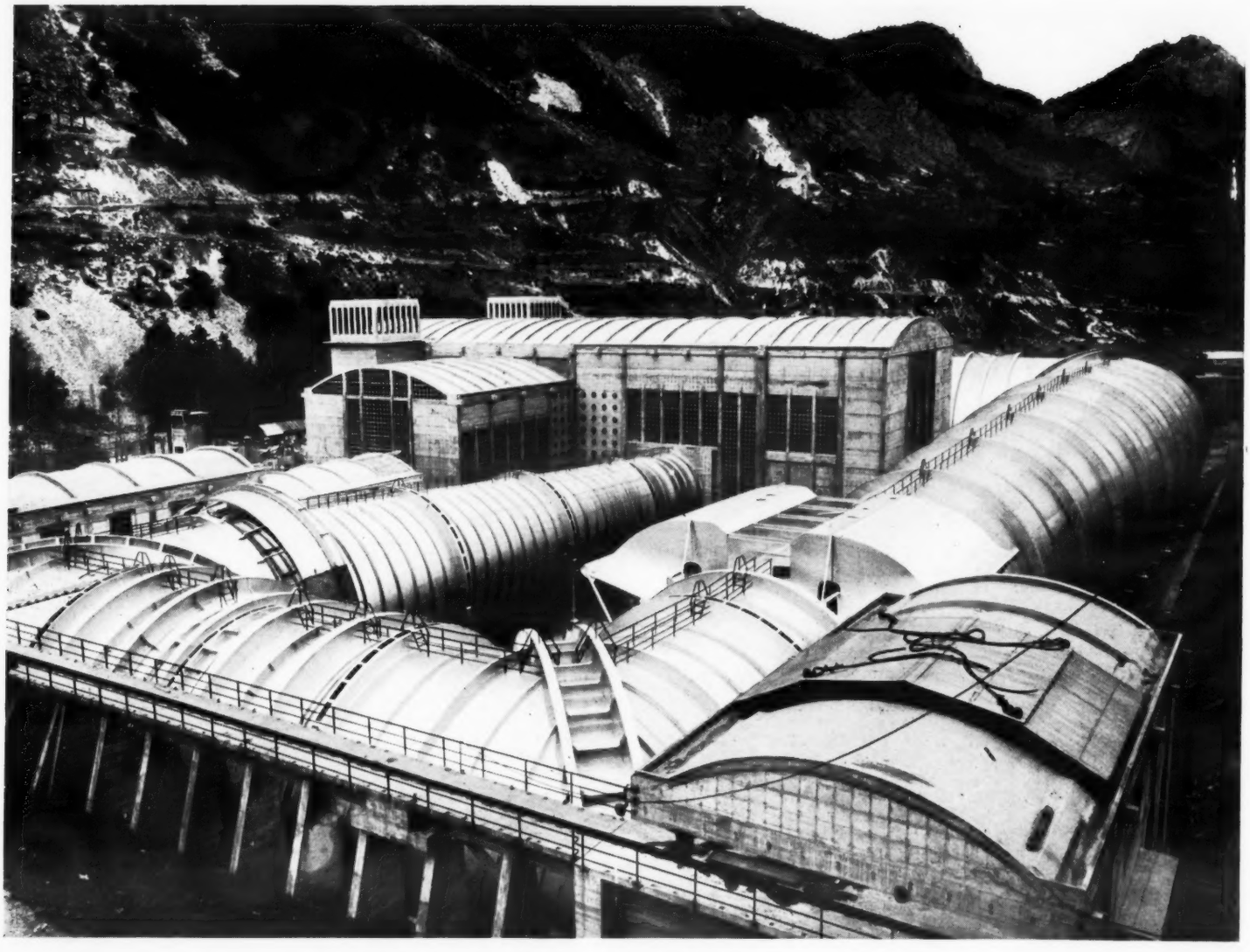
INTERAVIA

REVIEW OF WORLD AVIATION



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IN THIS ISSUE

In Europe's Laboratories

VOLUME VIII 7 1953

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Review of World Aviation

Volume VIII | No 7 | 1953

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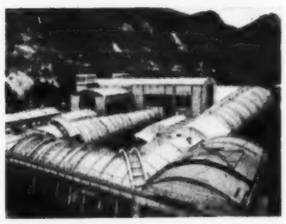
Contents

IN EUROPE'S LABORATORIES

Europe's Scientists and Engineers need Modern Equipment 375
Europe Laid the Foundations 376
New Tools for the Old World P. M. GALLOIS PARIS 379
Italy's Contribution to Aeronautical Research G. A. CROCCO, ROME 382
British Aeronautical Research and Development Sir H. M. GARNER, LONDON 385
Aeronautical Research in France M. ROY, PARIS 390
German Aeronautical Research seeks New Roads A. BETZ, GÖTTINGEN 393
What the Smaller Nations are Doing 395
Ramjets and the Work of René Leduc 400
Accent on Defence or a Sound Economy? 404
What's in the Air? 407
Standardization of Approach Procedures for Modern Radio Aids (II) P. CAROUR, PARIS 409



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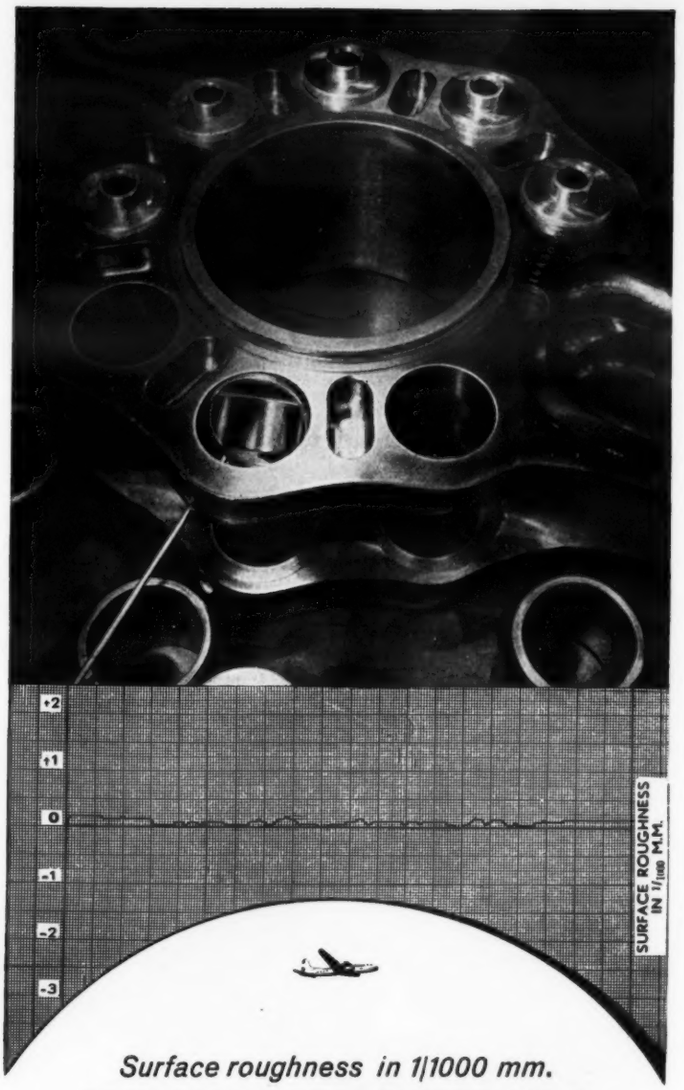

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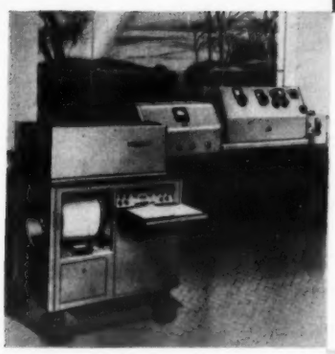

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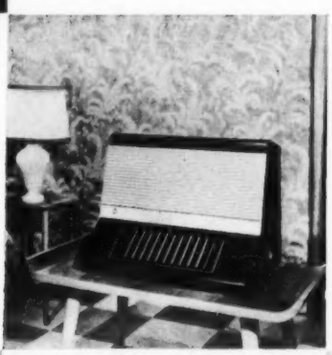

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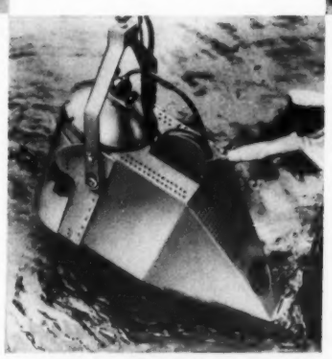

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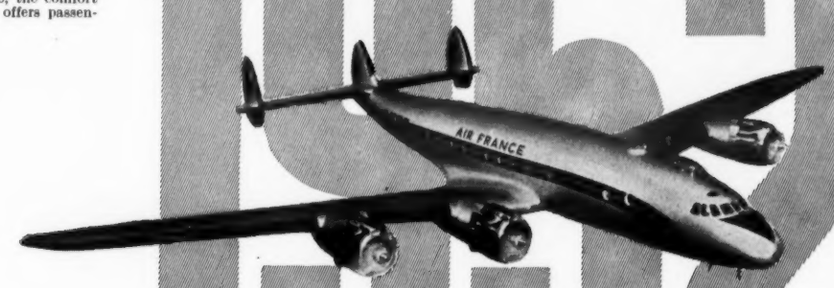
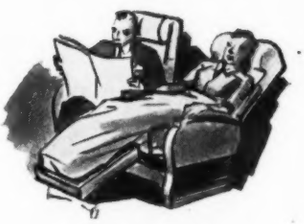
1952



A constructive year, as the following facts show

The opening of several new routes brought Air France's network up to 250,000 kilometres.

APRIL :	Opening of the Paris-Mexico City service.
NOVEMBER :	Paris-Tokyo in 37 hours 30 minutes flying time by "Constellation".
DECEMBER :	Installation of sky lounge chairs on one of the Paris-Casablanca services. New luxury service to Dakar.
JANUARY 1953 :	Air France opened the Paris-Caracas-Bogota service.



Air France is doing its utmost to bring the aircraft within reach of all :

— *" tourist class " has been introduced on some routes.*
— *major reductions have been agreed to on others.*

Air France is constantly improving and modernizing its fleet. During 1952, the famous Lockheed "Constellation", nicknamed the "Atlantic favourite", came into general use on the principal routes.

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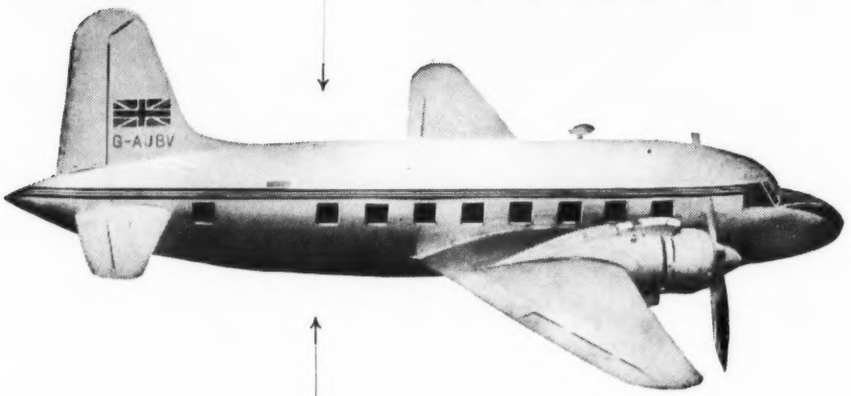
These aircraft are now OFFERED FOR SALE either singly or in fleet units, together with spares and ground equipment. Hire Purchase terms will be considered, also part purchase, part leasing arrangements.

The aircraft are the long-nose, metal-wing version of the Vickers Viking and, whilst at present equipped to carry 27 passengers, Aviation Servicing will undertake to carry out conversion if required, to increase the capacity to 36-38 persons.



Vickers Viking aircraft are of proven reliability and have been operating on the European routes with great success.

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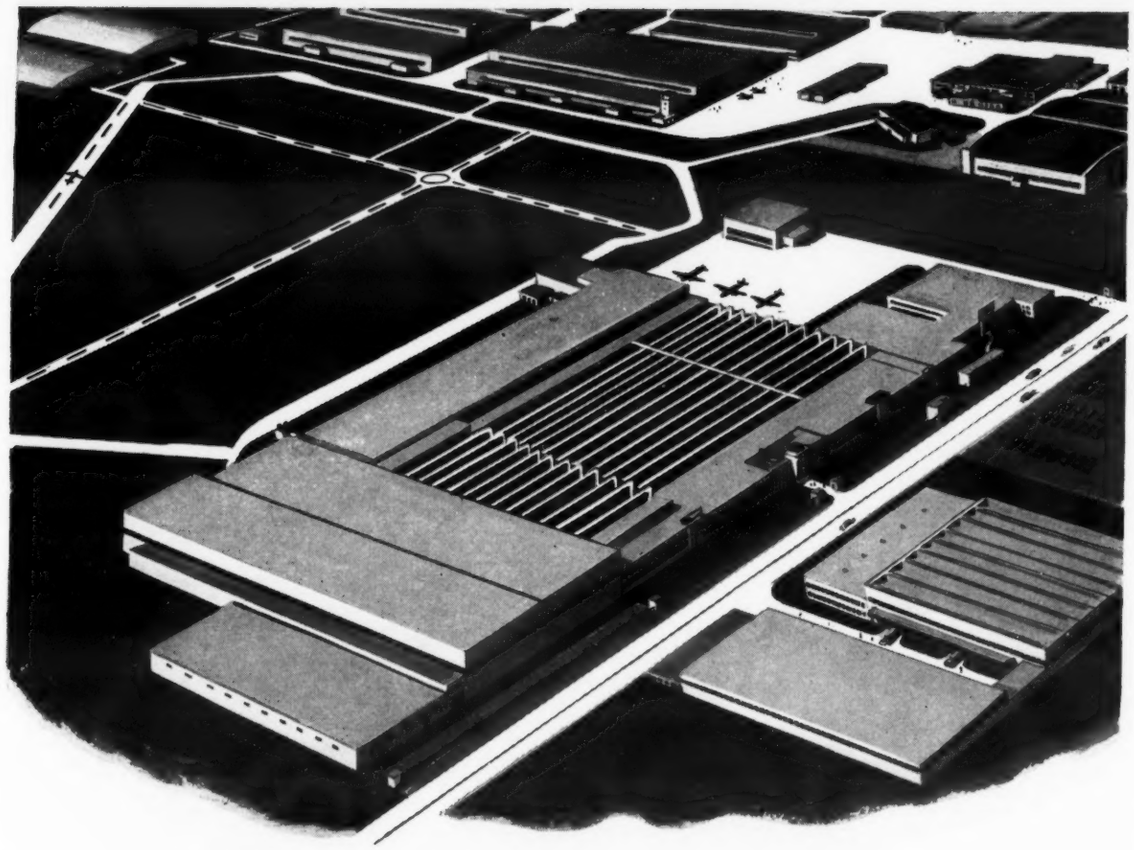

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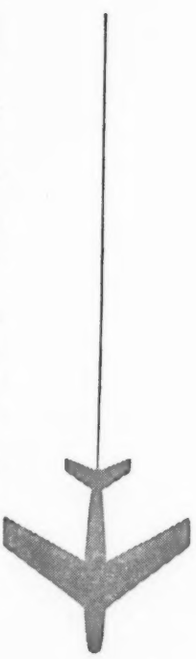

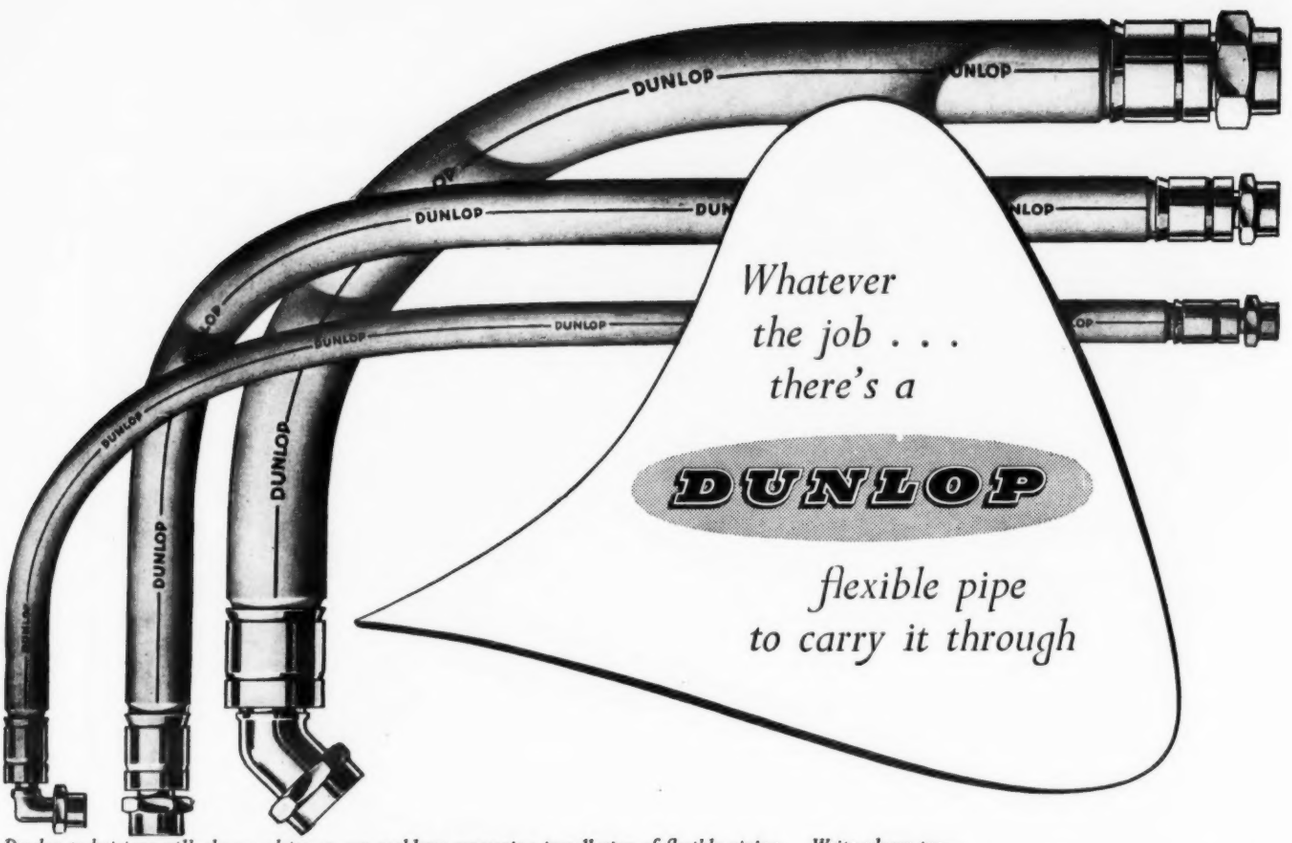

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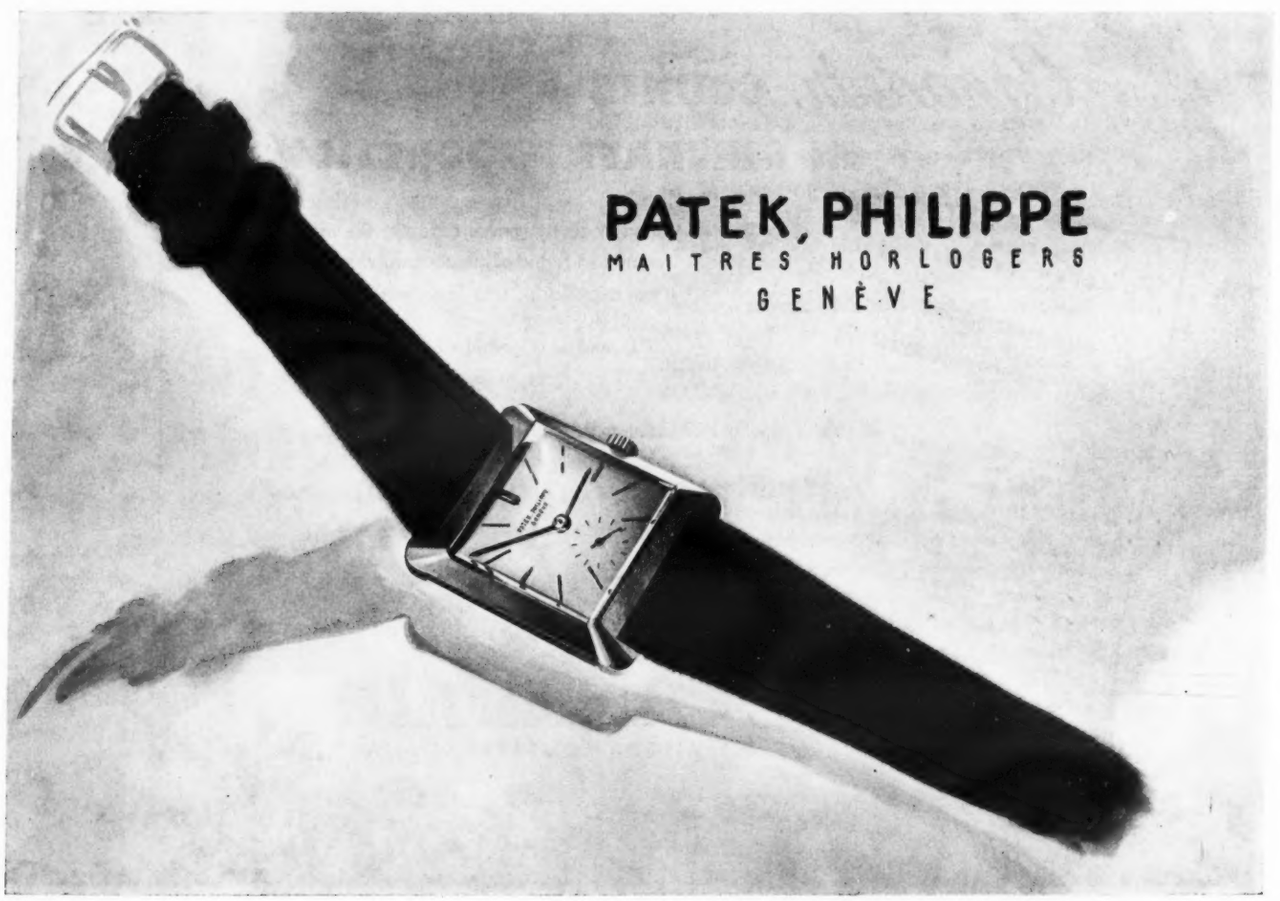

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The Saab-29 can be used for a variety of military duties, including interception, attack, and reconnaissance. For a swept-wing jet the Saab-29 has very moderate runway requirements.

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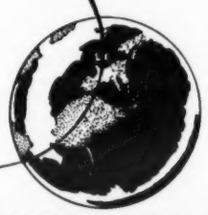

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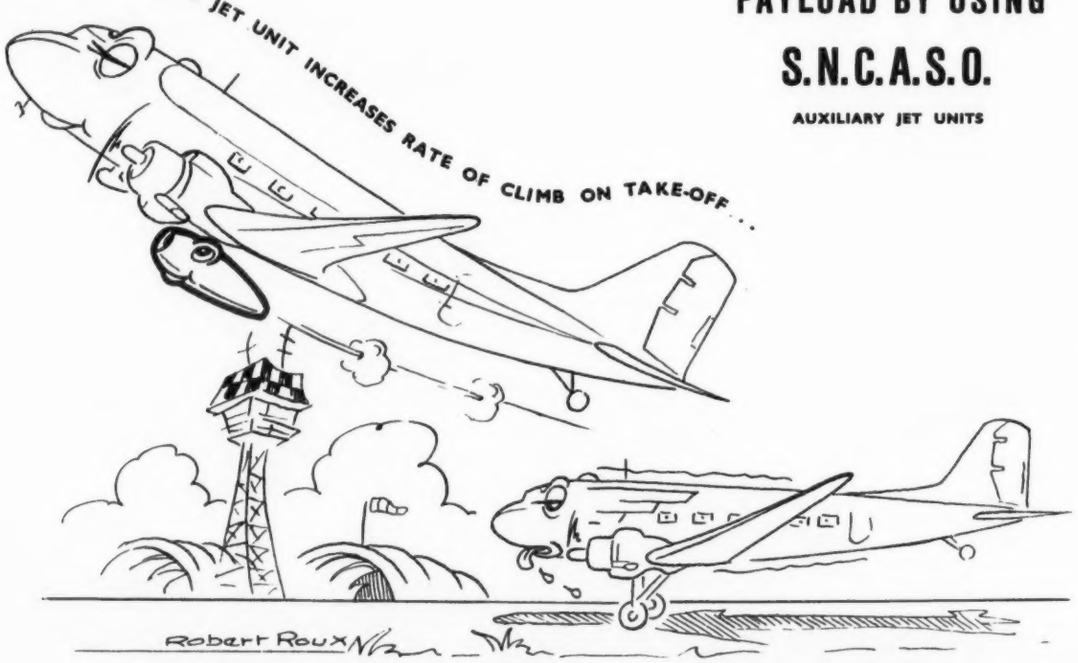

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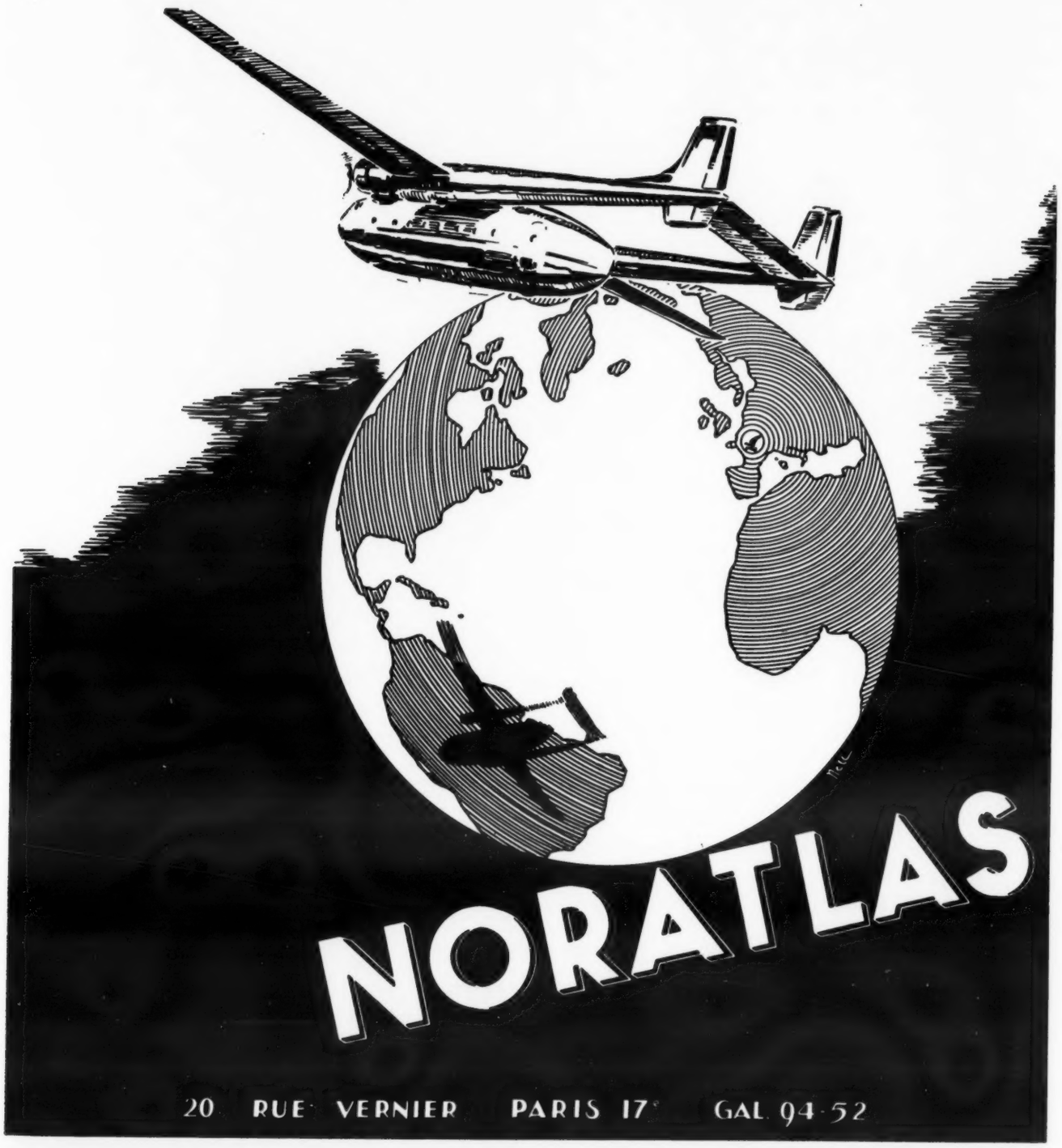

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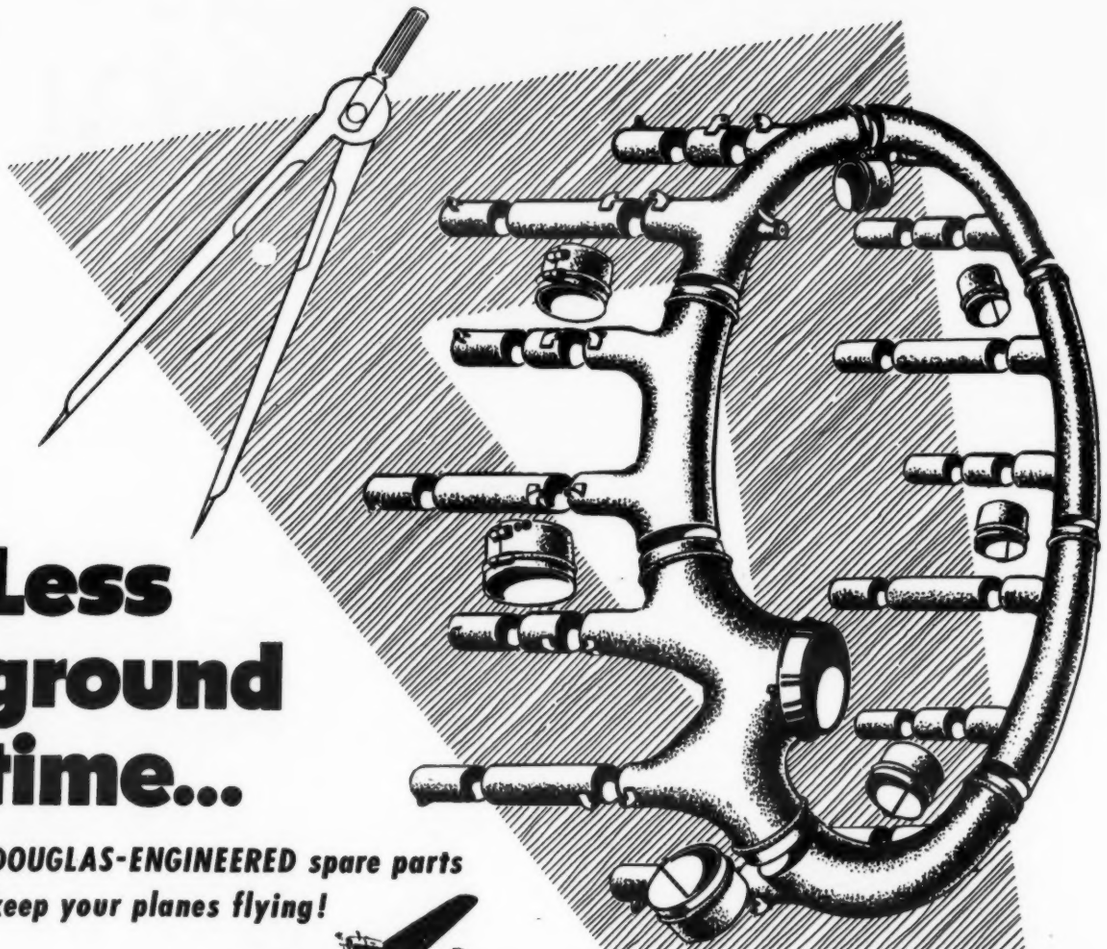

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INTERAVIA

Deadline Notes

No. 7/1953

THE BATTLE OF THE U.S. AIR FORCE BUDGET (cf. elsewhere in this issue) seems to be on the verge of terminating. On June 27th a major victory was won by President Eisenhower and his Defense Secretary, Charles E. Wilson, when the House Appropriations Committee not only sustained the roughly $5,000,000,000 slash proposed by Wilson for the USAF budget, but even recommended that Air Force funds be cut by an additional $240,000,000. With this, and with further cuts recommended by the Committee for the other two armed services, the controversy may end up with Eisenhower and Wilson fighting for certain restorations ... - instead of slashes. As it now appears, the Bill has every chance of passing, without major changes or further controversy, in the House on July 2nd.

U.S. AIR FORCE HAS KILLED CONTRACTS held by Kaiser-Frazer Corp. for 159 Fairchild C-119 Packet and 244 Chase C-123 transports valued $423,000,000. Fifty-seven C-119s have already been delivered. - Congress has been worried about the high cost of Kaiser's C-119s ($1,347,000 instead of Fairchild's $265,000). The move exemplifies Defense Secretary Wilson's intention to abolish the "dual source of supply policy". Efforts are being made to negotiate a new aircraft contract for the huge Willow Run plant and its 12,000 workers. USAF has also cancelled - though not because of high prices - its $100,000,000 contract with Canadair Ltd. of Montreal for the manufacture of 227 Beech T-36 twin-engined crew trainers. The contract for 193 such trainers held by Beech Aircraft Corp. was killed at the same time.

*

UNITED AIRCRAFT PROPOSES TO LICENCE GERMAN FIRMS for the production of engines, accessories and helicopters, United President H. Mansfield Horner said in Bonn June 25th. Horner and his party are reported to have conducted negotiations with Daimler-Benz for the production of Pratt & Whitney engines, with Robert Bosch for Hamilton-Standard accessories, with Heinkel and Weser Flugzeugbau for Sikorsky helicopters (S-55 ten-seaters ?). - Bayerische Motorenwerke (BMW), who built P&W radials before the war, is said to have shown little interest in a contract because its financial resources are fully tied up in other projects.

REPUBLIC AVIATION CORP., of Farmingdale, L.I., and S.N.C.A. du Sud-Est have signed an agreement under which the French company will build parts for the Republic F-84F Thunderstreak fighter-bomber, in wide use by the N.A.T.O. air forces. The first contract involves more than $30,000,000. S.N.C.A.S.E. expects to build complete Republic aircraft (type not designated) later on. - Republic now has two European subsidiaries: Republic Aviation (International) S.A., of Lugano, Switzerland, which at present is empowered to distribute USAF off-shore contracts involving up to $50,000,000; and Republic Aviation S.A. of Paris, which awards and finances contracts in France.

S.N.C.A. DU SUD-EST has concluded an agreement with Fiat S.A., of Turin, providing for the manufacture of Sikorsky S-55 helicopters for the European market. Fiat will make mechanical components, and S.N.C.A.S.E. will produce rotors and fuselages in cooperation with S.N.C.A.S.O. and Bréguet.

* From INTERAVIA's world-wide news service, including INTERAVIA AIR LETTER, the daily international aviation news digest. — No part may be reproduced without written permission.

ARMSTRONG-SIDDELEY MOTOR LTD. and Société des Avions Marcel Dassault have concluded an agreement under which the French company will produce the A.S. Viper expendable small jet engine under licence. Dassault may develop a new version of the Viper.

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REPRESENTED AT THE 20TH PARIS INTERNATIONAL AIRCRAFT SHOW, which was held from June 26th to July 5th were 186 exhibitors from nine countries, including 111 French firms. In the static show were 43 aeroplanes and helicopters; the flying display included 40 aircraft.

REAR ADMIRAL (RET.) LEWIS L. STRAUSS, New York financier, has been nominated Chairman of the Atomic Energy Commission in succession to Gordon Dean. The nomination must be confirmed by the Senate.

PLANS FOR A SERIES OF BRITISH ATOMIC WEAPONS TESTS on the Woomera Range, Australia, have been announced in the Commons by Supply Minister Duncan Sandys. The first British A-weapon was exploded at Monte Bello, off the Australian Coast, last October.

INDIA WILL GET 71 DASSAULT MD 450 OURAGAN JET FIGHTERS under an agreement signed in Paris June 25th. The Indian Air Force is also showing interest in the Ouragan's successor, the Dassault MD 452 Mystère.

NEW S.H.A.P.E. CHIEF OF STAFF: Lieutenant General Cortlandt Rensselaer Schuyler, U.S. Army. He succeeds General Alfred N. Gruenther, the new Supreme Commander, Allied Powers Europe.

PRESIDENT EISENHOWER REFUSES to use the safety seat belts in his personal Constellation, the "Columbine", on landings and take-off, according to Senator Karl E. Mundt, quoted by U.P. The President "sits riding backward behind his desk with his head against a partition of the plane ..." - An argument for the rear-facing seat advocates.

REGULAR HELICOPTER "POLICE BEATS" were inaugurated in New York City June 25th. Chief purpose is rescue work, but anything "suspicious" along the waterfront will also be reported by the "Flying Flatfeet."

ESTABLISHMENT OF A CHILEAN MINISTRY OF CIVIL AVIATION has been urged by General Arturo Benitez, President of Linea Aerea Nacional de Chile (LAN). Civil Aviation now is the responsibility of the Air Ministry.

BRITISH EUROPEAN AIRWAYS refuses to comment on rumours that it may scratch its entry of a Vickers 701 Viscount turboprop airliner in the Harewood Gold Cup race from England to New Zealand next September. It is said that participation in the race would interfere with BEA's Viscount schedules which are proving to be extremely popular.

PACIFIC WESTERN AIRLINES LTD. has been formed at Vancouver, B.C., through the merger of several small carriers. It is the third largest Canadian airline, after Trans Canada Air Lines and Canadian Pacific Airlines.

LATEST U.S. ENTRANT IN THE JET AIR TRANSPORT RACE - following Boeing, Douglas, Lockheed, and possibly North American - is Fairchild Engine and Airplane Corp., which has approved a "multi-million dollar" research and development programme for this purpose.

YUGOSLAVIA RECEIVED "MAJOR DELIVERIES" of Republic F-84 Thunderjet fighter-bombers towards the middle of last month. Eight were seen flying over Belgrade June 10th. Previous U.S. jet aircraft deliveries involved a number of Lockheed T-33 trainers.

Europe's Scientists and Engineers Need Modern Equipment

Speaking at the 8th National Aeronautical Congress of Italy, *G. Gabrielli, Managing Director of the Fiat concern,* discussed the question of wind tunnel facilities and underlined the necessity of giving Italy the research equipment necessary for modern aerodynamic research. Signor Gabrielli estimated that 30,000,000,000 to 35,000,000,000 lire ($45,000,000 to $50,000,000) would be required to provide his country with a minimum of essential scientific and technical equipment. He pointed out that, while this sum might seem considerable, it was insignificant in comparison with the 200,000,000,000 lire ($300,000,000) allocated that year (1948) by the United States for the accomplishment of their own aeronautical research programme. Gabrielli concluded by demanding the formation of a committee capable of establishing an equipment programme for Italy's aeronautical research activities, to be spread over several years. The same committee was also to work out a programme of collaboration between friendly countries in order to achieve a kind of division of duties among allied nations, since it was no longer possible for any one European country to cover the whole field of research.

In France, although the research facilities have been reconstructed and considerably expanded beyond their pre-war size, similar preoccupations are becoming discernible in the face of the multitude of tasks to be fulfilled. During a talk on a subject closely related to that mentioned by Signor Gabrielli, *H. Brocard, Chief Engineer of the Louis Bréguet aircraft company,* insisted on the necessity of relatively low-speed wind tunnels as well as of high-speed variable density tunnels like those existing at Pasadena and Cornell. So vast is the experimental field that numerous aircraft types designed in Europe in recent years have had to undergo their wind tunnel tests in the USA.

Thousands of interesting ideas evolved in Europe, hundreds of promising projects and dozens of valuable research studies have to be abandoned every year because of insufficient financial, engineering and experimental resources. Today, the financial means that must be invested are so great that it is no longer sufficient to present a complete dossier of theoretical studies to mobilize the private or public resources necessary for their realization.

The method followed is the same everywhere :

An original idea provokes a purely theoretical study.

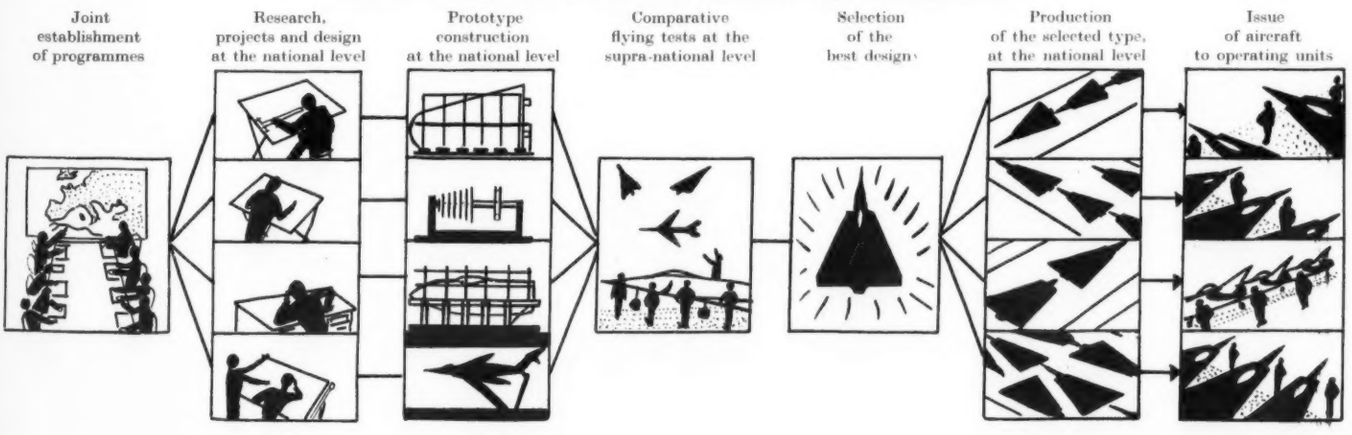
If the theoretical calculations confirm the value of the project, an experimental study is called for.

If the experiments, carried out on a small scale, confirm the accuracy of the theoretical calculation, then public or private capital may be invested, either for a new series of experiments on a larger or full scale, or for the building of a prototype—if the risks involved are considered acceptable.

In most cases the inventor lacks the means of completing the primary experimental stage. In order to provide assistance in such cases, a scientific organization was created by the United States in Brussels last year. This fact alone shows how necessary it is for the nations of Western Europe to organize themselves to facilitate the growth of the one section in which they excel: that of invention.

But in order to ensure that an organization of this kind is fertile, especially in the increasingly complex field of the aeronautical sciences, it is essential that the outlines of the research programme be traced on a generous scale and that cooperation be encouraged beyond national frontiers. This is the only way in which it will be possible to pool the scientific equipment which is becoming more and more extensive and consequently further and further beyond the reach of national resources, already incapable of dealing with the problems to be solved.

Diagram for a Joint Aeronautical Research and Development Organization

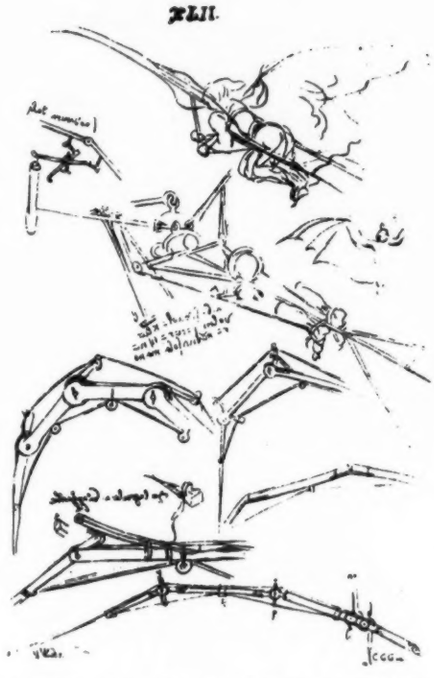

Joint establishment of programmes
Research, projects and design at the national level
Prototype construction at the national level
Comparative flying tests at the supra-national level
Selection of the best design
Production of the selected type, at the national level
Issue of aircraft to operating units

Europe laid the Foundations

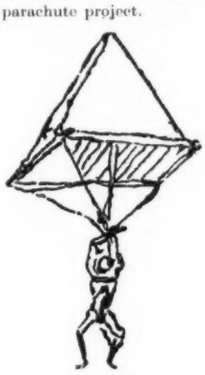
It is generally recognized that *modern aeronautical research* did not begin until the early years of the present century. The question, however, of when the actual foundations for this branch of research were laid is more difficult to answer. Being a *branch of the natural sciences*, the theory of flight is based on practically all aspects of mathematics, physics and chemistry, and is inseparably associated with other branches of research.

The majority of historians (including Sir James Jeans) [1] date the *birth of modern science* from the fall of Constantinople in 1453—exactly 500 years ago—and the consequent migration of scholars (and their libraries) to the West. This westward movement may be compared in rough extent and effect with the exodus of leading European scientists across the Atlantic after 1933 and 1945. Without the conquest of Constantinople—now Istanbul—by the Turks, the dissemination and development of Greek and Arabic mathematics in Europe would inevitably have greatly delayed.

The middle of the 15th century, however, brought two other decisive events: in 1441 Johannes Gutenberg invented printing, and Leonardo da Vinci, the first "modern" engineer, was born in 1452. Leonardo's importance in modern engineering is so well known that only a few examples need be mentioned: military machines, water wheel lathe with flywheel, parachute, human-powered aircraft, helicopter, etc. He also had pioneering knowledge in the field of science—law of falling bodies, law of inertia, aerodynamic phenomena—which, although remaining unknown to many up to their publication by Venturi in 1797, doubtless stimulated the Italian scholars (in particular Benedetti and Galileo).



About 1480: Leonardo da Vinci's muscle-powered flying machines and parachute project.



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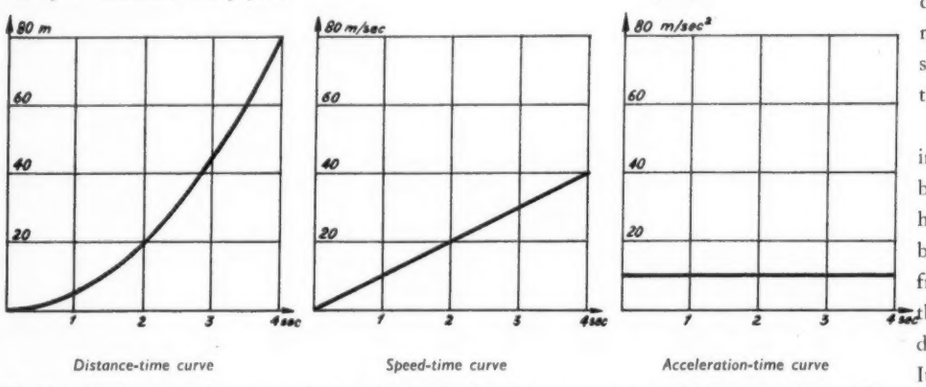
What then is the "secret" of this occidental science, which has brought us in a bare 150 years from the horse-drawn cart to the supersonic aircraft and the atom-powered submarine? It lies in the faithful observation of nature and in the consistent application of mathematical aids to thinking. During the past 500 years scholars have relied far more on their eyes and powers of logical assessment than on texts handed down from earlier generations or on misleading intuition. Precise, systematic observation has increasingly displaced philosophical speculation, and the mathematics of the ancients, who knew neither a systematic set of numerals nor the notion of functions, was transformed into the circumscribed system with which we can today express both the infinitely large and the infinitely small.

What the introduction of *Arabic numerals* by Leonardo of Pisa in 1202 meant to Western science and engineering will be clear to anyone who tries, for example, even to add together the Roman figures XXVII and XIV. (Incidentally, the sum is XLI . . .) An abacus was needed for an "operation" which every schoolboy can do in his head today . . . and there was no such thing as multiplication tables.

It is not quite so simple to explain the importance of the *notion of functions* which, to be exact, Descartes was the first to formulate in his analytical geometry.[2] This notion is at the basis of all achievements of European science from Newton's laws of dynamics to Einstein's theory of relativity. Every drawing office diagram, every production curve, is a function. It was the study of Descartes' works that



Distance-time curve — Speed-time curve — Acceleration-time curve

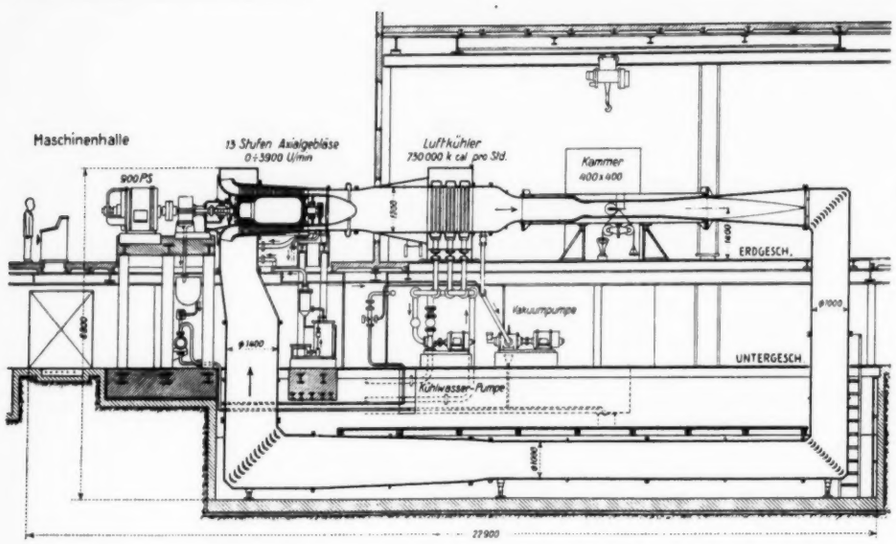
What is a function? The dependence of one variable value (e.g. distance covered, speed etc.) on another variable value (e.g. time). The speed-time curve can be derived from the distance-time curve, as speed is *change* in distance per unit of time (method of differentiation; discovered and named by Newton and Leibniz). Conversely, the acceleration curve gives the speed curve, which in turn gives the distance-time curve (method of integration; Leibniz-Newton). The latter method was used, for example, in operating the combustion cut off control for the V2 rocket.

[1] *Sir James Jeans:* "The Growth of Physical Sciences," Cambridge 1947, a very instructive work on the history of mathematics and physics.

[2] Third appendix "*La Géométrie*" (1638) to "Discours de la Méthode" of 1637. With Descartes (1596–1650), another Frenchman, Fermat (1601–1665), is regarded as the founder of analytical geometry.

Some Inventions of Importance to Aviation

Mathematics, physics, chemistry				Tools, machinery, technology			
Year	*Discovery/Invention*	*Name*	*Country*	*Year*	*Discovery/Invention*	*Name*	*Country*
600 B.C.	Bases of mathematics and geometry	Thales	Milet	260 B.C.	Screw block and pulley	Archimedes	Syracuse
530 B.C.	Arithmetic, plane geometry, well-known theorem	Pythagoras	Samos	250 B.C.	Toothed wheel and piston pump	Ktesibios	Alexandria
300 B.C.	Elements of geometry (and optics)	Euclid	Alexandria	100 B.C.	Temple automats and steam wheel	Hero	Alexandria
150	Trigonometry, apparent course of planets	Ptolemy	Alexandria	30 B.C.	Military machines	Vitruvius	Rome
350	Mathematical equations	Diaphantos	Alexandria	850	Wheel-clock	Pacificus of Verona	Italy
800	Indian numerals, algebra	Al Kirismi	Arabia	1180	Compass	—	Europe
1202	Arabic numerals	Leonardo of Pisa	Italy	1320	First powder weapons	—	Germany
1460	Decimal system, trigonometry	Regiomontanus	Germany	1441	Printing	Gutenberg	Germany
1543	De Revolutionibus Orbium Coelestium	Copernicus	Poland	1480	Water wheel, ornithopter, helicopter	Leonardo da Vinci	Italy
1596	Laws of falling bodies, pendulum laws	Galileo	Italy	1500	Pocket watch	Henlein	Germany
1609	Laws of planetary motion	Kepler	Germany	1500	First lathe with flywheel	Leonardo da Vinci	Italy
1614	Logarithms, slide rule	Napier	England	1590	Microscope	The Janssens	Holland
1638	Completion of analytical geometry	Descartes	France	1600	First telescope	—	Holland
1643	Laws of air pressure, barometer	Torricelli	Italy	1642	First calculating machine	Pascal	France
1661	Relationship between gas volume and pressure	Boyle	England	1650	Air pump	Guericke	Germany
1665	Infinitesimal calculus (published 1704)	Newton	England	1657	Pendulum clock	Huygens	Holland
1676	First calculation of speed of light	Römer	Denmark	1662	Friction electrolysing machine	Guericke	Germany
1678	First wave theory of light	Huygens	Holland	1666	Reflecting telescope	Newton	England
1684	Differential and integral calculus	Leibniz	Germany	1690	Atmospheric piston steam engine	Papin	France
1687	Basic laws of dynamics	Newton	England	1698	Steam pump	Savery	England
1738	Calculation of speed of sound	Paris Academy	France	1714	Mercury thermometer	Fahrenheit	England
1738	Foundations of theory of fluids	D. Bernoulli	Switzerland	1726	Blower	Roots	England
1755	Text book of differential calculus	Euler	Switzerland	1740	Blast furnace; cast steel	—	England
1766	Discovery of hydrogen	Cavendish	England	1747	Reaction water wheel	Segner	Germany
1771	Discovery of oxygen	Priestley	England	1769	Steam engine patented	Watt	England
1778	Foundation of modern chemistry	Lavoisier	France	1782	First hot air balloon	The Montgolfiers	France
1800	Electric current, battery	Volta	Italy	1783	First hydrogen balloon	Charles	France
1808	Foundations of atomic theory	Dalton	England	1801	First steam automobile	Trevithick	England
1820	Electro-magnetism	Oersted	Denmark	1804	First steam locomotive	Trevithick	England
1820	Basic principles of electro-dynamics	Ampère	France	1807	First paddle steamer	Fulton	USA
1824	Principles of thermodynamics	S. Carnot	France	1812	Ship's screw	Ressel	Austria
1825	Benzol	Faraday	England	1825	Steam railway	Stephenson	England
1831	Electro-magnetic induction	Faraday	England	1833	Electro-magnetic telegraph	Gauss/Weber	Germany
1833	Absolute system of measurement	Gauss	Germany	1855	Decarbonization of pig-iron by air	Bessemer	England
1842	Law of the conservation of energy	R. Mayer	Germany	1860	First gas engine, spark plug	Lenoir	France
1843	Measurement of the mechanical equivalent of heat	Joule	England	1862	Four-stroke gas engine	Beau de Rochas	France
1857	Kinetic gas theory, theory of entropy	Clausius	Germany	1867	Dynamo	Siemens	Germany
1864	Electro-magnetic theory of light	Maxwell	England	1871	Aircraft model with rubber band engine	Pénaud	France
1867	Dynamo-electrical principle	Siemens	Germany	1872	First dirigible with gas engine	Hänlein	Austria
1869	Periodic system of elements	Mendeleieff	Russia	1878	Telephone and microphone	Bell/Hughes	USA
1883	Theory of electrons	Lorentz	Holland	1879	Electric light bulb	Edison	USA
1887	Radio waves	Hertz	Germany	1883	First petrol engine	Benz	Germany
1889	Supersonic pressure waves on shells	Mach	Austria	1884	Dirigible with electro-motor	Renard/Krebs	France
1895	X-rays	Röntgen	Germany	1885	First petrol car	Daimler	Germany
1896	Radio-activity	Becquerel	France	1891	First manned glider	O. Lilienthal	Germany
1897	Mass and charge of electrons	Thomson	England	1893	Carburettor	Maybach	Germany
1898	Radium	The Curies	France	1895	Patent for rigid airship	Zeppelin	Germany
1900	Quantum theory	Planck	Germany	1897	Diesel engine	Diesel	Germany
1904	Distance Measuring by radio waves	Hülsmeyer	Germany	1897	Radio-telegraphy	Marconi	Italy
1905	Foundations of wing theory	Joukowsky	Russia	1898	Cathode ray tube	Lenard	Germany
1905	Equivalence of mass and energy	Einstein	—	1903	First successful powered aircraft	Wright Brothers	USA
1913	First atom model	Bohr	Denmark	1904	Gyro compass	Anschütz	Germany
1919	Transmutation of nitrogen into oxygen	Rutherford	New Zealand	1905	Duralumin	Wilm	Germany
1920	Isotopes	Ashton	England	1907	First subsonic wind tunnel with closed circuit	Prandtl	Germany
1924	Foundations of physics of waves	de Broglie	France	1907	First manned helicopter	Cornu	France
1927	Principle of uncertainty	Heisenberg	Germany	1923	Autogiro	de la Cierva	Spain
1932	Demonstration of neutron	Chadwick	England	1931	First cyclotron	Lawrence	USA
1932	Demonstration of positron	Anderson	USA	1933	First supersonic wind tunnel	Ackeret	Switzerland
1939	Splitting of uranium atom	Hahn	Germany	1953	Atomic engine (submarine)	A.E.C.	USA



Since 1933 : Supersonic wind tunnel for twice sonic speed at the Aerodynamics Division of the Swiss Federal Institute of Technology.

led both Newton and Leibniz—working quite independently of one another—to the invention of the *differential and integral calculus.*

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Incorruptible judgment and tireless observation enabled Copernicus (died in 1543), Tycho Brahe and Kepler to overthrow the ancient conception of the world and formulate the laws for the motions of planets. At the same time Galileo, experimenting with pendulums and falling bodies (1596), expanded the static mechanics of the ancients into the *dynamic mechanics* of modern times. Finally, Newton, drawing on both sources, completed this system of mechanics with his three basic dynamic laws [3] and the law of gravity.

Now at last the systematic pursuit of the exact sciences could begin, such as the foundation of the *theory of fluids* by the Basle mathematicians Daniel Bernoulli (Hydrodynamica, 1738) and Leonhard Euler, *on which the theory of flight is based.*

The two Basle scholars were not only master mathematicians, but also primarily *experimental physicists.* Thus they were as far removed from philosophico-logical speculation as from the purely mathematical speculation of many of our own contemporaries. The latter should take note of Bernoulli's saying : "A dangerous taste is beginning to infiltrate, through which the true sciences will suffer much more than they will be advanced, and it would often be better for the *realem physicam* if there were no mathematicians in the world."

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[3] *Isaac Newton :* "Philosophiae Naturalis Principia Mathematica," London 1687.

D. Bernoulli's and Euler's time also saw the great discoveries of the chemists : hydrogen, oxygen, nitrogen, etc. They formed the basis for modern *chemistry* as initiated by Lavoisier (1778) and for meteorology, the creation of the internal combustion engine, the balloon, high altitude flight, etc. Contemporary technical inventions included the first blast furnaces and steam engines, and, not least, the invention of cast steel, without which modern industry, for example the engine industry, would be unthinkable.

The foundations had been laid. But it was not until the nineteenth century that the theories were put into practical application. In *thermodynamics* we find a step-by-step development from the basic writings of Sadi Carnot,[4] the "father of thermodynamics," through Robert Mayer's law of the conservation of energy and Joule's almost simultaneous measurement of the mechanical equivalent of heat . . . up to the building of the first gas engines by the Frenchmen Lenoir and Beau de Rochas, and finally the first petrol and heavy oil engines by the Germans Benz and Diesel. Another important discovery that should not be passed over in silence was that of benzol by Faraday.

The second, no less grandiose line of development—that of *electrophysics*—begins in 1800 with the building of the first electrical battery by the Italian Volta and leads via Oersted (Denmark), Ampère (France) and Faraday (Britain) to the electrical machines of Werner von Siemens, the discovery of radio waves by Hertz and the construction of the first radio telegraph by Marconi.

[4] *Sadi Carnot :* "La force motrice du feu," Paris 1824.

The electron theory of the Dutchman Lorentz, the invention of X-rays by the German Röntgen, the discovery of radioactivity by the Frenchman Becquerel and the Curies prepared the ground for the consummation of *Western physics :* Planck's quantum theory, Einstein's theory of relativity, de Broglie's physics of waves. This type of physics by no means loses itself in speculations but rather is the mother of the atomic piles and power plants which are already equipping submarines (U.S.S. *Nautilus*) and tomorrow will supply wide regions of the earth with power or drive giant airliners.

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Space limitations prevent us from going into details of these developments. However, we have compiled a table of the most important discoveries and inventions on which modern aviation is directly or indirectly dependent. This table contains more than a hundred names and dates but could easily have been doubled or trebled in length. The left-hand portion shows the course of "pure" science—so to speak the theory of basic research ; the right-hand portion is a list of the aids to research—tools and machinery—and of inventions based on theoretical physics. Both sides of the table are closely interconnected. For example, it was not until Guericke had invented the air pump—a practical invention—that the relationship between pressure and volume of gases could be discovered (Boyle-Mariotte's law). *It will be seen that aeronautical research did not begin until very late—not until 1903 as scientific research—i.e., after four-and-a-half centuries of basic research.*

On the practical side of the development of aviation, reference need only be made to the small aircraft model driven by an elastic band and a propeller, built by the Frenchman Pénaud (1871), and the 2,000 or so gliding flights by the German Otto Lilienthal (1891 to 1896). The results of this vital preparatory work had only to be combined with a sufficiently light and powerful engine . . . and human flight became a reality.

This final triumph was denied to the Frenchman Clément Ader (*Eole* steam-driven aircraft of 1890) and the Austrian Kress (powered flying boat of 1901). Two Americans, the brothers Wilbur and Orville Wright, finally carried off the palm, thanks not least to their novel catapult arrangement. This *pioneering achievement by the New World* is undisputed, but the fact remains that... *Europe laid the foundations.*

New Tools for the Old World

BY LT.-COLONEL PIERRE M. GALLOIS, PARIS

The evolution of the engineering sciences has completely upset the hierarchy of nations. The fact is self-evident today. With its imperative requirements and the imposing array of working facilities it demands, this evolution threatens to sterilize the creative idea because it paralyzes it whenever a country's economy or industry is too poor to assure its financial support. Nobody would contest the intellectual power of the old Western World, however many criticize the West's failure in the field of concrete achievement, experimentation, development and practical utilization. As regards the aeronautical sciences, it is a commonplace to list side by side the very useful ideas that have been generated in the West and the corresponding achievements which have been derived from them in other parts of the world.

Frequently, and in several fields of endeavour, there seems to be a wide gap between the "creative idea" and "practical achievement." Countless are the projects which, in this Europe of ours, have been abandoned at the laboratory, the planning or even initial conception stage, because the means to determine their potential value were lacking. In contrast, Rear-Admiral De Witt C. Ramsey, President of the U.S. Aircraft Industries Association, a year ago demanded an annual intake of 60,000 new engineers and technicians, compared with a training rate of only 26,000 in 1952. It was estimated at the time that 150,000 American scientists and engineers were engaged in research work, at an expenditure of about $3,000,000,000 including about $500,000,000 for aeronautical purposes. This averaged roughly $25,000 per scientific worker, i.e. nearly three times the corresponding figure reached in periods of prosperity and, therefore, generosity by certain scientific-technical organizations in Western Europe.

On May 18th, 1953, the U.S. National Manpower Council submitted a 263-page report to President Eisenhower drawing attention to the shortage of highly-qualified specialists and suggesting measures to restore the country's "intellectual and scientific balance." The fact is that in the field of aeronautical research alone, considerable sums of money are handled by the research organizations who need a great many gifted scientists if these investments are to pay. Without counting special allocations and expenditure by private research units, the 1953-1954 national defence estimates provided $ 840,000,000 for aeronautical research and development, i.e., more than half of the entire British military air estimates. And in 1949, i.e., before the rearmament of the Western World, it was agreed that a new aeronautical research centre should be created in the United States, the ultimate cost of which was expected to be well in excess of $1,000,000,000. These tremendous financial efforts have further lengthened the lead which aeronautical science on the Western shores of the Atlantic managed to acquire during World War II. They have also enabled the Americans to make good the lags in certain fields which had been neglected in favour of the quantity production of combat aircraft. An American engineer, in fact, wrote some time ago : "We thought that we would fly at 1,200 miles an hour in about 1985. Research has enabled us to gain 34 years on our initial estimate."

However, this means that enormous investments in brain-power, instrumentation and other equipment of all kinds have been necessary. The cost in time and money of constructing a big modern wind tunnel are well-known. The acquisition of a test site and its equipment as a missile-firing range at Point Mugu, in California, for example, involved an expenditure of $500,000,000. The 20-mile runway and scientific and test equipment at Edwards Air Force Base on Muroc Dry Lake, California, also devoured vast sums of money. Large funds have been invested in the fantastic computing machines without which exploration of space and investigation of the higher speed ranges by piloted aircraft and especially pilotless missiles would be all but impossible. When these investments are backed, as in the United States, by sales which will reach $20,000,000,000 this year and provided $6,000,000,000 in 1951 for the purchase of aircraft alone, they are not out of proportion to the overall expenditure on aeronautics. In contrast, examination of the French and British air appropriations shows that expenditure on production is of an entirely different order of magnitude, since it remains below $300,000,000 at the peak period of aerial rearmament.

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In the United States, as everywhere else, research and development are conducted by a great variety of methods. They may take the form of impressive groups of scientists and

What the Americans are spending on aeronautical research : Pressure tunnel at NACA's Langley Memorial Aeronautical Laboratory, Hampton, Virginia *(left)* ; it has a measuring section 19 ft. in diameter and pressure can be raised to $2\frac{1}{3}$ atmospheres. *Right :* Hypersonic tunnel at California Institute of Technology for speeds up to Mach 10.

technicians, numbering thousands of highly-qualified personnel and using equipment worth millions of dollars, or of small research teams and modest laboratories producing results which complement those obtained from the large-scale facilities. Very often the solutions provided for specific problems by these small teams are most ingenious and therefore just as valuable as the work done by the big research centres. It is nevertheless a fact that, however small the volume of industrial production, a minimum of scientific equipment is indispensable, although the cost of such equipment is increasingly disproportionate to the markets open to the countries of Western Europe at home or abroad. This fact has been emphasized in the past three years in the examination of various rearmament plans. The "medium size" nations, namely those which are not as great as the giants that have arisen in the past twenty years but whose possibilities nevertheless are vast, are facing the following dilemma : either they devote their resources to the creation of an adequate research and development apparatus on a national scale, in which case not much money is left to make full use of this apparatus ; or else they endeavour to strike a balance by creating more modest research facilities and seek to employ them to the full, in which case both the apparatus and its products may be unsatisfactory.

For many years experts have been studying the problems presented by the new burdens of design and engineering. The simplest solution, which is, however, the most difficult to apply, *is to go beyond national boundaries,* pooling scientific capital, test and experimental facilities, and markets.

*

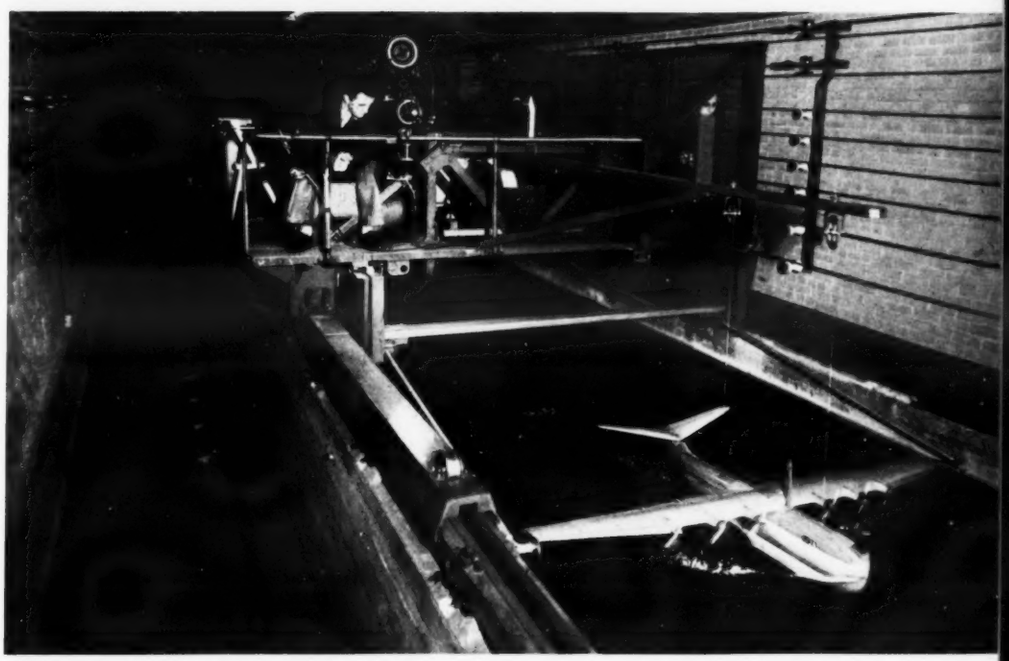
A common bond: the lack of resources

The drawbacks of association are well-known, but "needs must when the devil drives." The years to come will show if a country below a certain size will be able to continue to engage in purely "national games" in such advanced fields of engineering as aeronautics. However, to move from the present national basis to a supra-national one is no easier in the engineering than in the political field.

The first measure to be taken would be the elaboration of programmes designed to serve as guiding lines for aeronautical research and development. This task should be carried out by military and civil users of aircraft. It is up to them to study their problems and fix their goals. Independently of political considerations and without taking into account the great political projects now being worked out in Western Europe, these aims must be defined in relation to individual theatres of operation or areas of utilization. Like the Convair B-36 super-bomber or the intercontinental civil airliner, not all types of aircraft are suitable for every geographical or economic region of the

FRANCE : The big wind tunnel at Modane-Avrieux with a 110,000 h.p. power source ; it has its own hydraulic power plant.

BRITAIN : Supersonic wind tunnel of the National Physical Laboratory (measuring section 10 × 10 in.). *(Crown Copyright).*



BRITAIN : Tow tank at the Royal Aircraft Establishment, Farnborough, with scale model of the Saro SR/45 giant flying-boat ; the tank is 660 ft. long and permits of towing speeds up to 40 ft./sec. *(Crown Copyright).*

planet. Those who are able to organize their defence in depth will be less exacting as regards the rate of climb of their interceptors, but they will insist on sufficient endurance. Others, with a vast territory to protect, will define vital zones, rather than plan to procure air defence equipment for the whole area, which would be difficult to protect efficiently. For certain groups of nations, ground attack operations will be of immediately decisive importance, since no ocean, no sea, no natural anti-tank ditch protects their approaches. For others, prevailing meteorological conditions require an especially strenuous effort in the fields of instrument flying techniques, and of sustained all-weather offensive and defensive action. This worry is shared by all, and no nation can be indifferent to the problem of keeping its air forces in continuous action. But the problem is less critical in Italy, for example, than in Great Britain, and certain gaps in aircraft equipment can be tolerated on the shores of the Mediterranean but not in the North Sea. In brief, the various requirements of a military, technical, economic, geographical and meteorological nature will determine the choice of performance characteristics and therefore trace the lines to be followed by the research effort.

In determining these research and development requirements, social and even psychotechnical factors must also be taken into consideration. Technical luxury, necessary in one case, can be dispensed with in others, where the personnel is more ready to put up with a low degree of comfort or certain other limitations. Economically, finally, ideas applicable to the richest are not valid for others. Thus, the lack of certain so-called "strategic" materials will make a shorter life of jet engines or a higher rate of fuel consumption acceptable to some and at the same time reduce complexity and manufacturing costs.

Standardization of civil aviation equipment is more easily achieved. There are, however, a few sub-categories which must be more precisely adapted to their zone of utilization. The opening up of Africa, for example, and more generally all the regions situated between the same parallels and still devoid of road and rail communications, necessitates fairly specialized aircraft which still remain to be developed.

*

Thus, the range of flying equipment to be developed covers a vast number of variants. Needless to say, the requirements of the different theatres of operations or geographic regions will show numerous common features which are expressed in the individual national aircraft engineering trends. Added to this is the inescapable fact that the nations of Western Europe, apart from their economic and psychological similarities, will be called upon to share in the defence of a single theatre of operations.

This general definition of the aims to be achieved must be discussed jointly by the military, as the users, and the scientists, who in this case will act as advisers : the scientists will trace the general limits within which the military can fulfil their ambitions. In this manner a final programme, flexible enough for the technicians to work at ease and clear-cut enough to provide a guiding line for their research work, can be prepared.

There is no doubt that such plans will encounter numerous difficulties in practical application. However, if these difficulties are balanced against the advantages to be gained, it will be seen that it would pay to attempt the realization of the project. It would bring about the elimination of a great deal of duplication in research, as well as standardization at an early stage of design, the possibility of choosing from a larger range of types, the pooling of intellectual and material resources.

One of the first prerequisites would be to adapt those parts of national legislation dealing with rights to manufacturing methods and patents. Furthermore, existing security regulations would have to be modified. Considering what has already been achieved in this respect in the field of military alliances, it will be admitted that under the pressure of necessity the difficulties are not insurmountable.

The corollary to such a coordination of effort would be the pooling of the "ground facilities" required by research and development. This might involve existing wind tunnels, electronic computers, test centres for flying equipment and the famous guided missile ranges which are beginning to stretch across the continents as a result of the advent of long-range missiles. Thousands of other research facilities which have become indispensable to modern aeronautical progress, for research on aerodynamics, combustion, communications or aeronautical medicine, could work more efficiently if their capacities were properly coordinated. In view of the present state of their industries and their economies, the nations of Western Europe will one day be *forced* to acquire the "scientific tools" they need to keep abreast of the evolution of aeronautical research and development.

Italy's Contribution to Aeronautical Research during the First Twenty Years of the Century

BY PROFESSOR GAETANO ARTURO CROCCO, INSPECTOR-GENERAL, AIR ENGINEERS CORPS, ROME

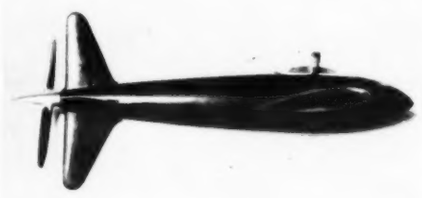
Born in 1877, Gaetano Arturo Crocco joined the Brigata Specialisti *of the Italian Army Engineers Corps in 1900, where he remained until 1923. He was then appointed Director-General of Industry at the Ministry of National Economy. In 1927 he was called to the University of Rome, where he now holds the chair of general aeronautics. In 1928 he rejoined the Engineers with the rank of Lieutenant-General, becoming Director of Building and Supply at the Air Ministry and later Director of Research and Development (until 1933). He was elected to the* Accademia dei Lincei *in 1919, the Italian Academy in 1932 and the Papal Academy in 1936, and received the gold medal of the* Académie des Sciences, *Paris, and a gold medal from the Lombard Institute of Science and Letters.*

During the meeting of the Advisory Group for Aeronautical Research and Development in Rome a few months ago [1] I had the honour of presenting a specially compiled bibliography of aeronautical research in Italy, which listed some 1,200 papers, and of illustrating certain points for the benefit of the meeting.

Here, therefore, I shall restrict myself to throwing some light on Italy's contribution to the history of human flight during the twenty years before the spectacular unfolding of American aeronautical research.

This latter development, which began in 1915 with the creation of the National Advisory Committee for Aeronautics, was in fact most probably influenced by creative thought in Europe, whose radiations America was able to pick up and return to the world amplified and transformed.

Neither of the two almost contemporary events which marked the double birth of aviation—the Wright brothers' flight in 1903 and Kutta-Joukowsky's theory of 1902-1905—succeeded in arousing much attention in America. I say double birth because aviation was born in two cradles : the cradle of the art of flying—the *how* of flight—and the cradle of the science of flying—the *why* of flight.



Monoplane (designed by Crocco), built by the *Brigata Specialisti* of the Italian Engineer Corps in the spring of 1903. For ascending or descending flight and for banking, the wings, attached elastically to the fuselage, were warped individually by means of a single control lever.

But the Wright brothers kept the secret of their technique for five years and did not come to Europe until the art of flying had developed along different lines in France, and *Blériot* was about to cross the Channel in his monoplane. Meanwhile the science of flight, born of the inspired intuition of Lanchester, had been elaborated by *Prandtl* and *Karman* and their followers, who defined the physical phenomena of lift and drag in fluids and whose work was first described in America in a NACA report in 1921.

*

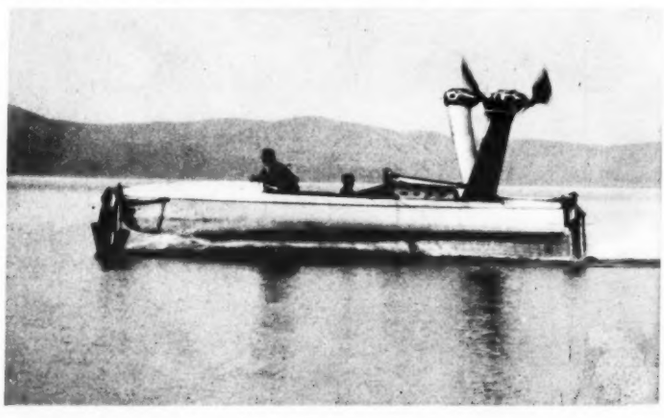
Italy's contribution to aeronautical research was of course only a part of Europe's radiation during the first twenty years of the century, but it had the singular good fortune to be supported by the faith and enthusiasm of *Mario Maurizio Moris,* at that time a Major in the *Brigata Specialisti* in Rome.

Moris gave his support to the original ideas of Engineer Enrico Forlanini, who was then building a semi-rigid airship of his own design ; however, he was already thinking of a "heavier-than-air," but foresaw the difficulties such a

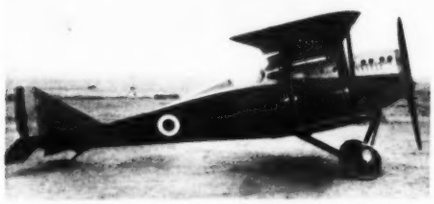
[1] Advisory Group for Aeronautical Research and Development—Report by G. A. Crocco.—December 17th, 1952.

Hydrodynamic lift produced by underwater sponsons lifted this hydroplane of Enrico Forlanini's out of the water. The boat, a patent for which was applied for in 1904, was designed as a transition stage towards a future aircraft project.

Also fitted with underwater sponsons, the hydroplane (type C.R.) built by the *Brigata Specialisti* was used from 1906 on for testing airship engines. Picture shows the second model (1907) moving at 50 m.p.h. on Lake Braceiano.



The first controllable-pitch propeller (for change in pitch during flight) was developed by the *Brigata Specialisti* in 1907. Its blades were gimbal-mounted. — Picture shows a 1912 version of this propeller as it was fitted to the gondola of a German rigid airship. The same propeller was also demonstrated in London in 1916.



The SVA biplane (with 200 h.p. SPA engine), a design by Capt. R. Verduzio (who worked with U. Savoia and C. Rosatelli) of 1916, was tried out at Villacoub.ay in October 1917 by the Technical Section of the French Air Force : it reached a level speed of 81 m.p.h. and climbed to 16,400 ft. in 15 minutes. A model of the whole aircraft and one of the fuselage and wings were examined at the Istituto Centrale Aeronautico and at Dayton, Ohio.

Two-seat day bomber by Engineer O. Pomilio, with 400 h.p. twelve-cylinder *Liberty* engine, developed for the American Government at Indianapolis, Indiana.

Single-seater fighter by Engineer O. Pomilio, with 280 h.p. eight-cylinder *Liberty* engine, developed for the American Government at Indianapolis, Indiana.

craft would have in taking off without adequate speed. Nevertheless he had thought up a system of launching it on the water from a boat propelled by airscrews and supported by small sponsons resting on the water. But the years passed.

Moris then decided to give Forlanini his best assistant, Lieutenant Cesare Dal Fabbro, creator of the first Italian aerostat and of the whole balloon organization of the *Brigata Specialisti*. He also started a number of young officers of the *Brigata* on a parallell track, instructing them to design a dirigible which could be built quickly.

Dirigibles were already flying in Europe, but aerodynes had scarcely begun to unfold their wings. However the creation of an airship technique prepared the way for the development of flying in Italy. Much of what determines the success of an aeroplane was already implicit in the airship, in particular aerodynamic lift, with the sole difference that this lift co-existed with the static lift which the aeroplane could not have.

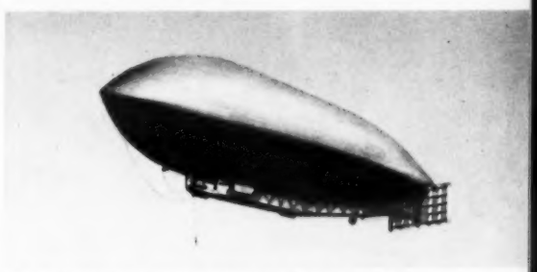
It was the study of aerodynamic lift in airships which made possible the first Italian theory of the stability of flying machines[2] and led to the first hydrodynamic[3] and aerodynamic experiments. During the years that followed, the *Istituto Centrale Aeronautico*, of Rome, built its big closed-circuit aerodynamic wind tunnel, which took its place in European research next to Eiffel's tunnel in Paris and Prandtl's at Göttingen.

Meanwhile, design and construction of engines was going on almost independently of the machines they were to power. The same applies, even more forcibly, to the fundamentals of aeronautics, an ultra-light structure subjected to high stresses. For example the framework of airships, stabilizer longerons, joints and hinges, steel tubes and duralumin extrusions, all the machining refinements made by the *Stabilimento di Costruzioni Aeronautiche*, of Rome, and the Crescenzago works at Milan ; all the stress calculations made by our design offices ; all the tests—everything was gradually adapted from the airship to the aeroplane and culminated in the structure of the *SVA*,

[2] Report by G. A. Crocco to the *Académie des Sciences*, Paris, in December 1904 ; report to the *Accademia dei Lincei*, in 1909, extending the theory to aerodynes.

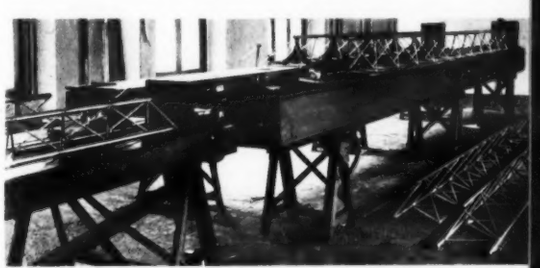
[3] Using the Brigata Specialisti's water tunnel, Capt. Giulio Costanzi discovered the important phenomenon of the transition of laminar boundary layer flow into turbulence on blunt bodies (spheres and circular cylinders), which leads to a sudden reduction in drag coefficient: Costanzi described his observations, in 1912, to the French engineer G. Eiffel, who confirmed them in the aerodynamic field, without however mentioning the earlier Italian experiments.

Italian Airships

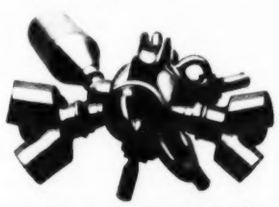


The first steam-powered airship built by Enrico Forlanini, the *Leonardo da Vinci*, took to the air in 1909. Picture shows the *Città di Milano* in flight in 1913. Altogether six airships of this type were built, three for Italy, three for the British Admiralty.

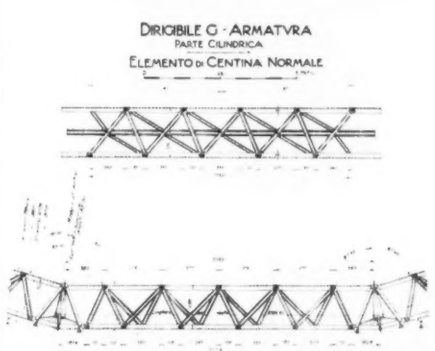
The prototype of the Italian military airship was seen over Rome on October 31st, 1908. Three years later, a type P airship took part in the campaign in Libya, and types M and V were used in World War I. A class M airship was also bought by the British Admiralty, and another *(Roma)* by the United States in 1919.



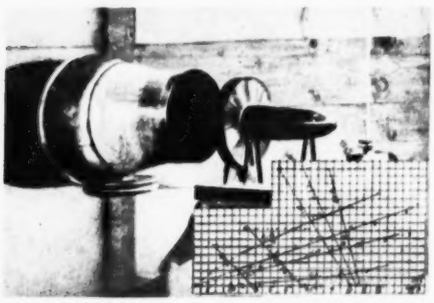
Steel-tube grid bearers (Italian patent No. 95604 of May 11th, 1908) formed the load-bearing structure of Italy's semi-rigid airships.



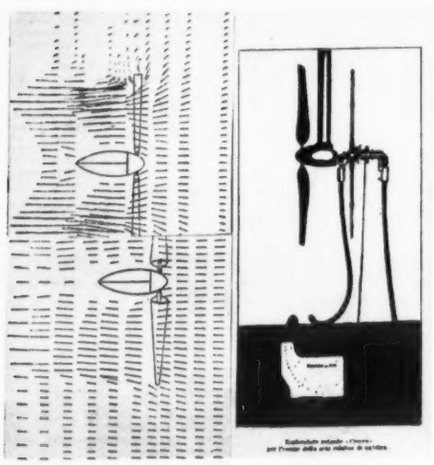
Jointed connection in the framework of a semi-rigid airship (1908) : all struts and bracing wires end in steel connecting pieces which allow them a degree of static freedom (Del Fabbro and Forlanini method).



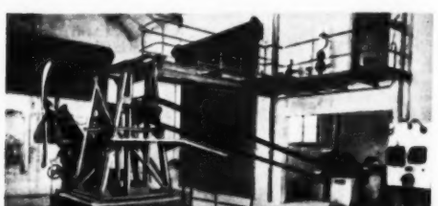
Structure of a normal bulkhead of enclosed duralumin bearers (built in 1912).



The first flow tests were made by the Brigata Specialisti in 1904 with paddle wheels rotating in the gas jet of an oxygen generator. Right, measurements taken at the time.



Measurements of flow round a propeller by means of the Brigata Specialisti's "Esploratore Rotante," in 1906. This was the first time measurements of this kind had been made "point by point"; top left, results for calm air, bottom left, for air in motion.



The Research Institute of Turin Technical University began work in 1915, thanks to the efforts of Prof. M. Panetti. Equipment included this reaction balance for aircraft engines, developed by Prof. A. Anastasi. A little later a wind tunnel was built, which served Italian aviation for 30 years.

the fastest military aircraft of World War II.

Italian developments were "imported" into Germany in 1913, and into France and Britain during the war. A collection of duralumin spars, extremely light in weight, was sent to London in April 1916 for the Admiralty.

America, which had remained in the background up to the end of 1915, suddenly began to absorb European thought, including that of Italy. Scientific and technical missions came to visit plants at Turin and Milan, the *Stabilimento di Costruzioni* in Rome and the *Istituto Centrale Aeronautico*.

One of our route indicators, designed for airships, was promptly exported to America and adapted to aeroplanes.[4]

Our *Telebomba*, the first self-controlled missile ever to fly—in July 1918—was immediately examined by the Allied Inventions Office, where America was represented by E. Buckingham, the mathematician.

In the spring of 1918, a year after entering the war, America had already sent a mission to Europe to visit aircraft factories and choose three industrial groups, one per country, so as to transfer European experience to the United States.

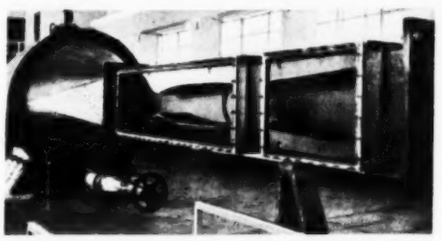
In Italy it was the Pomilio group that was chosen and went straight to Langley Field to design and build a fast fighter and day bomber.

The two prototypes were completed and successfully tested a few months after the Armistice. Engineer Ottorino Pomilio was then commissioned by the United States Navy to write a book, which appeared in 1919,[5] with an introduction by Professor I. S. McGregor, who said: "The publication of this book at this time is opportune, and it should go far toward replacing by scientific procedure many of the *cut and try* methods now used."

[4] NACA, Report No. 131, 1921, p. 776.

[5] O. Pomilio: "Airplane Design and Construction," McGraw Hill Inc., New York, 1919.

The Aircraft Engine Institute of the University of Rome made a large number of tests with solid-fuel rockets between 1927 and 1934. Left to right, by the pressure recording machine: Dr. Marenco; Prof. Crocco, senior; Prof. Crocco junior.

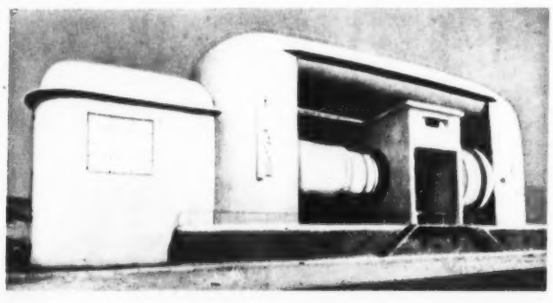


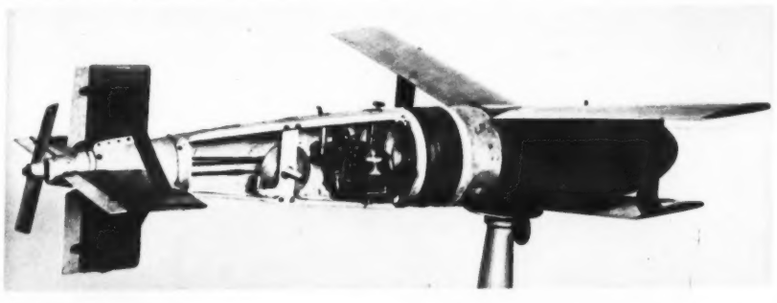
1938 — the closed-circuit supersonic tunnel at Guidonia research and experimental centre (destroyed during the war) was one of the most striking evidences of Italy's will to master the problems of flight. It was built by Brown-Boveri on the model of Prof. Ackeret's supersonic tunnel (Federal Institute of Technology, Zurich), but with a power of 2,810 h.p. (instead of 890 h.p.) and operated by compressed air, i.e. at correspondingly higher Reynolds numbers (measuring section $15^3/_4 \times 29^1/_4$ ins.). Important laws of supersonic flow were discovered with the aid of this tunnel, under the careful leadership of Dr. Antonio Ferri.

This course calculator for airships (Crocco type) made by the Istituto Centrale Aeronautico, dates from 1917. It was later used by the United States Navy. The instrument evaluates azimuth and time data, picks up the required course by means of an alidade and combines it with the compass reading and the logarithmic values for air speed and wind force.

The same year (1915) the *Brigata Specialisti's* aerodynamic research was transferred to the Istituto Centrale Aeronautico, which had an underground wind tunnel (Italian patent No. 141887 taken out in 1914). A similar one was later built above ground at Guidonia (picture).

Italian robot bomber (type C.G.) of 1918: launched from an aircraft, the engine-less miniature biplane reached speeds of up to 250 m.p.h. in a dive. It could then glide for a distance of up to 8 miles. A gyroscope (torpedo type) provided directional stability, and gliding angle was controlled by a propeller with distance measuring mechanism. The glide bomb was automatically stabilized about transverse and longitudinal axes: design, model tests and construction were carried out by the Istituto Centrale Aeronautico.





The European method has always been the opposite, to try before cutting.

At the same time, NACA opened its agency in Paris with the task of keeping in close touch with the scientific research in progress, in particular at Saint-Cyr aerodynamic laboratory in France, the National Physical Laboratory in Britain and the *Istituto Centrale Aeronautico* in Italy, as set out in the report to the U.S. Congress of December 1st, 1919.

This report stressed that although more than 13,000 aircraft had been built in the United States, there had been great delay in getting an efficient air force into action during the war, due in particular to the lack of proper scientific and technical bases before the war.

Aeronautical research in the United States made up for lost time in a very few years, and between 1925 and 1938 NACA astounded Europe with the scale of the scientific and experimental output of its Langley Field laboratories. Thus the ideas of 1918 came back across the Atlantic as though reflected by an immense electronic amplifier.

During the last few years before World War II, Europe, including Italy, was once more able to come to the fore in aeronautical research, but it is probable that the gigantic American amplifier will continue for some time to come to control the whole current of European production.

G. A. Crocco

British Aeronautical Research and Development

BY SIR HARRY M. GARNER, K.B.E., C.B., M.A., F.R.AE.S.

Photograph "The Aeroplane"

Sir Harry M. Garner was born in 1891 and educated at St. John's College, Cambridge. After a period of military service, he went to the Royal Aircraft Establishment at Farnborough in 1916, where he was employed in the Aerodynamics Department and took part as an observer in experimental flying. He was put in charge of the full-scale research in 1927 and in 1929 went to take charge of the scientific and technical work on seaplanes at the Marine Aircraft Experimental Establishment, Felixstowe. In 1942 he became Deputy Director of Scientific Research in the Ministry of Aircraft Production, and in 1946 Director of Research. He was appointed Chief Scientist in the Ministry of Supply in 1949, a post he held until his retirement early this year.

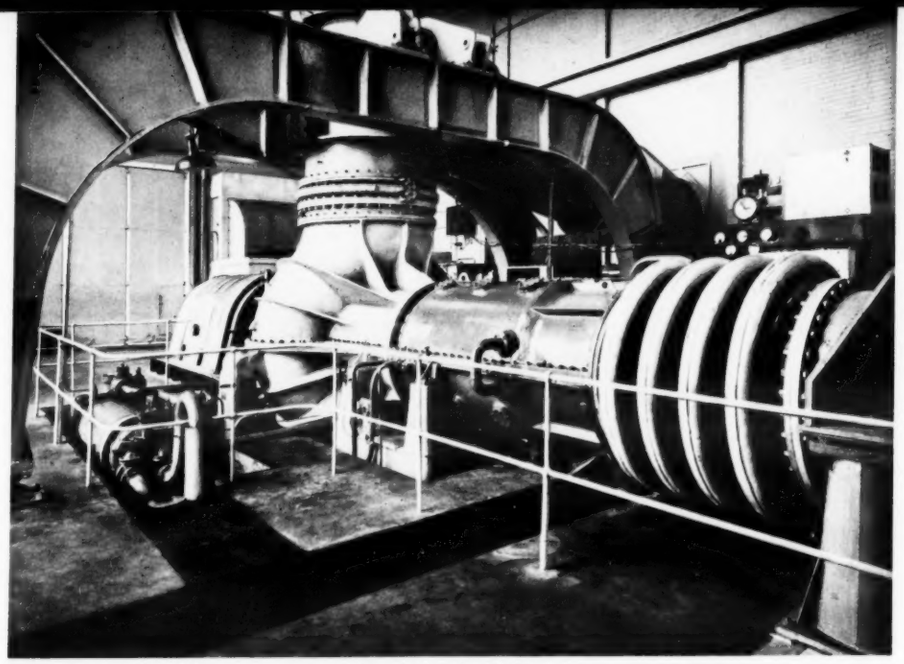
Growing Complexity of Research

The early pioneers in aviation concentrated all their skill in getting their aeroplanes into the air, with enough fuel to make a short flight. Even during the first world war the addition of a gun to a fighter or a few small bombs to a bomber was a formidable increase of load. The designer's main objective was the production of a good flying machine for which he needed a light and reliable internal combustion engine, a good knowledge of aerodynamics, in the broad sense, to be able to design an aeroplane of good shape and with good flying qualities. He was not greatly worried about the details of the military load. A good aeroplane could be adapted to take such guns or bombs as its performance would justify, and they were 'stuck on' in the most convenient place.

Since then every step in the improvement of the performance of aircraft has resulted in an increase in complexity of design. The retracting undercarriage, adjustable flaps and pressure cabins for high altitude flight are only a few of the complications that have made the airframe designer's lot more difficult. Power plants have become more and more complex, partly because they have to work under much greater variations of height and speed, and partly because they have to supply auxiliary power to a multitude of electrical and hydraulic devices. But the most difficult load imposed on the designer is caused by the fact that the aeroplane of today has such a good performance that it can carry equipment of great variety. The development of this equipment has more than kept pace with the capacity of the aeroplane to carry it. Radar and other radio devices, instruments of all kinds and automatic controls have enabled the spheres of activity of aircraft to be greatly extended. The equipment can no longer be put on after the design of the basic

aeroplane is finished. *The design is often dominated by the equipment from the start.*

The result of these developments is that aeronautical engineering has enlarged its scope to include almost every kind of modern engineering activity. Aeronautical research and development, whose job it is to serve the industry responsible for aircraft design has, of necessity, become equally diversified. It ranges from the study of the problems of high speed flight to the design of valves suitable for some piece of highly complex radar equipment.



Compressor for the 7,000 h.p. supersonic wind tunnel at the R.A.E.

Research Responsibilities and Principles

The responsibility for research and development in Great Britain lies almost entirely with the *Ministry of Supply,* which provides aircraft for both military and civil users. This arrangement has the great advantage that research and development on all types of aircraft, for the Royal Air Force, the Royal Navy, the Army and Civil Aviation, are all done side by side in experimental establishments. This is generally accepted as more than counterbalancing the disadvantage that there is liable to be some separation between the design of the aircraft and its operational use.

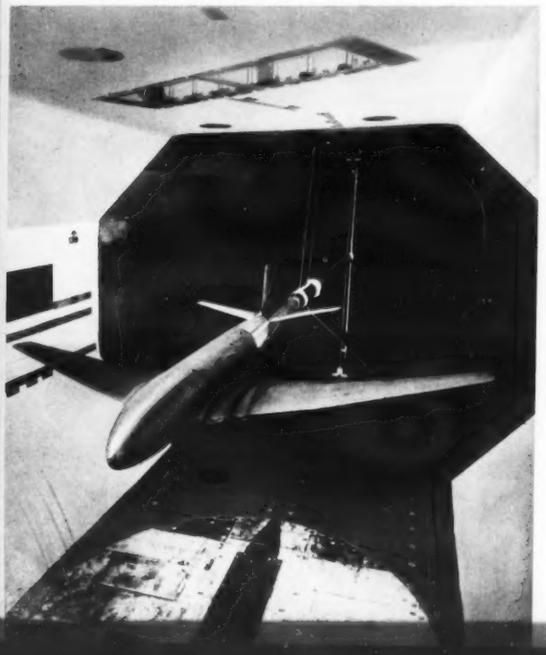
The British Ministry of Supply controls what is probably the largest single aeronautical research organization in the world. It includes a large directing headquarters and six experimental establishments ; it employs 2,400 scientists and engineers, and its total personnel strength is 15,000. The establishments between them cover every field of scientific activity relating to aeronautics, from basic work on materials and fuels to research on the full-scale gas turbine and the complete aircraft.

The principles employed in planning the research and development are those that have been adopted from the beginning of aeronautical research. The research starts in the laboratory, on models of aircraft or other apparatus designed to simulate flight conditions, and ends with research on the actual aircraft in flight. The provision of the right balance between work in the laboratory and work in flight is one that requires good scientific judgment and skill. It can only be achieved if the work is in the hands of first-rate scientists at all levels. This has been very much in mind in the planning of British aeronautical research.

Research and development must be closely associated with actual design if they are to be of full value. The experimental establishments provide the supporting work on which the aircraft industry depends. This work consists of three parts :

1. Work in advance of current designs in industry. This is the basic research needed for future designs.
2. Work on actual aircraft or equipment under design. This may include wind tunnel tests, structural tests, or the design of radio or instrument components and, in some instances, complete prototype equipment.
3. Investigations of difficulties that arise after the design is completed.

Model of the *Comet* jetliner in the high-speed wind tunnel at the Royal Aircraft Establishment.



Research Facilities

The six experimental establishments engaged on air research in the Ministry of Supply are :

Royal Aircraft Establishment (R.A.E.) ;
National Aeronautical Establishment (N.A.E.) ;
National Gas Turbine Establishment (N.G.T.E.) ;
Telecommunications Research Establishment (T.R.E.) ;
Aeroplane and Armament Experimental Establishment (A. & A.E.E.) ;
Marine Aircraft Experimental Establishment (M.A.E.E.).

The first four of these are engaged on research and development ; the main functions of A. & A.E.E. and M.A.E.E. are to test aircraft for their suitability for service use.

Royal Aircraft Establishment, Farnborough

The R.A.E. is the oldest and largest of the research establishments, and was originally engaged in work on airships. Research, development and design on aircraft started in about 1910. Today it is engaged on almost every aspect of aeronautical research, with a special emphasis on full-scale experimental work. It has twelve major departments which fall broadly into two groups. The first group deals with the problems of the basic aircraft and comprises aerodynamics, structures, materials and allied subjects. The second group deals with aircraft equipment including instruments, armament and radio.

Another view of the high-speed tunnel at the R.A.E. The model is that of a Hawker *Tempest* fighter.

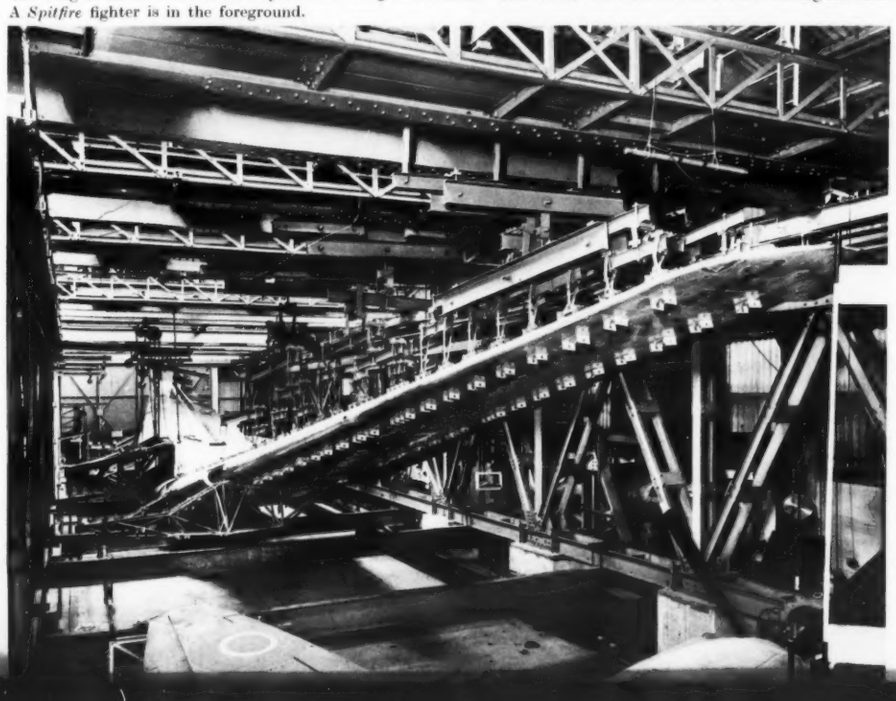
In the early days the items of equipment could be developed separately, but today each one of them reacts on the others, and they all have to be closely integrated into the basic aeroplane. Indeed, as I have already said, the design of a modern military aircraft may be dominated from the beginning by the need to fit a particular piece of equipment, such as a radar device.

The R.A.E. is a unique experimental establishment in that, with the exception of the gas turbine and radar, it deals with the whole field of aeronautical research. It is therefore able to take care of research problems that arise on the aircraft as a whole, such as, for example, when the fitting of armament affects the flying qualities of the aircraft and calls for special instrumental assistance. The R.A.E., for this reason, proved to be an ideal establishment to be given the charge of research and development on *guided weapons*. These, even more than the aeroplane, required co-ordination of all the components, each of which reacts on the others. A coordinating Guided Weapons Department was set up, which draws on the work of all the specialist departments at R.A.E. as well as other establishments in the Ministry of Supply. A special section deals with the design of the rocket motor and is fully equipped not only for research but for proof testing large rocket motors.

For guided weapon work special test ranges have been fitted with elaborate recording apparatus, which enables full particulars of each flight test to be obtained. For long-range work use is made of the Australian Long Range Establishment at Woomera, New South Wales, where tests can be made of guided weapons, of whatever the range, with little risk to human life and property. Although not under Ministry of Supply control, the range is available for the testing of experimental models and weapons designed in Great Britain.

The aerodynamic and structural research equipment at the R.A.E., in addition to a large number of smaller wind tunnels, includes a high speed subsonic wind tunnel 10 ft. by 8 ft., a group of continuous and intermittent supersonic tunnels, used mainly for guided weapon tests, driven by a plant of 7,000 h.p., and a large structural testing machine, known as the "Cathedral," with a span of 120 feet.

The wing of an Avro *Lincoln* heavy bomber being tested in the "Cathedral," the R.A.E.'s structural testing machine. A *Spitfire* fighter is in the foreground.



National Aeronautical Establishment, Bedford

In 1946 the Aeronautical Research Council was asked to advise on future British aeronautical research. They recommended the creation of a new establishment, and it was decided that the N.A.E. should be set up at Bedford, equipped with large wind tunnels, a long experimental runway and possibly with large-scale structural testing equipment. The main wind tunnels are a supersonic tunnel three feet square and a much larger one eight feet square, with a speed of three times that of sound, driven by a power plant of 60,000 h.p. The runway, 3,500 yards long and 100 yards wide, will be very suitable for testing novel experimental aircraft. The first tunnel is already in operation.

National Gas Turbine Establishment, Pyestock

The N.G.T.E. is responsible for research on all types of gas turbine, aeronautical, industrial and marine. The establishment is being re-equipped with large-scale equipment driven by a power system of 50,000 h.p. The equipment will enable components of large gas turbines such as compressors, combustion systems and turbines to be tested separately under conditions corresponding to all flight conditions, including high altitude. Large ramjets can also be tested with this equipment.

The N.G.T.E. was responsible for much of the pioneering work on axial flow compressors, which has led to the design of the *Sapphire, Avon, Olympus* and other successful British gas

turbines. It has done original work on exhaust thrust reheat systems, cooled turbines and precision casting of blades. Although the establishment does not actually design gas turbines, it has a great influence on design and has played a large part in maintaining the leading position that Great Britain holds in the field of aircraft gas turbines.

Telecommunications Research Establishment, Malvern

As the R.A.E. was built up as the result of the first World War, so T.R.E. was the product of the second. The early experiments on radar, started at Bawdsey in 1935, led to tremendous developments in a great variety of applications. Before the end of the war it was used for early warning, interception of aircraft, navigation and bombing, with great success.

T.R.E. today is engaged on the same problems as during World War II, with the emphasis on greater precision, range and freedom from interference. Apart from the design of equipment and components in their early experimental stages, before they are taken over by industrial designers, T.R.E. is responsible for basic research, which covers a very wide band of wave lengths, calling for original work on such subjects as low temperature physics and atmospheric absorption. Much of the work has important applications to civil as well as military aviation.

Aeroplane and Armament Experimental Establishment, Boscombe Down

The A. & A.E.E. started at Martlesham Heath in 1917 to make simple measurements of the performance of aircraft. The measurements at first were confined to take-off and landing runs, speeds, climbs and handling tests. As time has gone on, the scope of measurements has been extended. The results, reduced to standard conditions, constitute a record of the capabilities of the aircraft independent of the place and time of test. Martlesham figures have always had a world-wide reputation for reliability.

At its present site at Boscombe Down the A. & A.E.E. is still responsible for the assessment of military aircraft, but the scope of its work has been extended to cover tests of aircraft equipment such as armament, radio and instruments, as well as performance measurements of the basic aircraft. It has played an important part in standardising performance methods in cooperation with other countries.

Marine Aircraft Experimental Establishment, Felixstowe

The M.A.E.E., responsible for the performance testing of marine aircraft, grew up side by side with A. & A.E.E. It was established on its present site in 1924. The amount of performance work on marine aircraft has greatly diminished during the last ten years, and the establishment is engaged mainly on research, which is expected to have an important influence on future designs.

National Physical Laboratory, Teddington

No account of aeronautical research would be complete without a reference to the Aerodynamics department of the N.P.L., which has been engaged on this kind of work since 1909. The work is mainly confined to basic research on such subjects as supersonic and transonic flow, and boundary layer investigations. Although the Department does not belong to the Ministry of Supply, being part of the Department of Scientific and Industrial Research, the programme is closely co-ordinated with that of the R.A.E. and other establishments.

Operational Research

The design of military equipment must be closely matched to its operational use, and operational research sections set up to examine the behaviour of aircraft in operations and investigate the potentialities of new types to meet the military requirements. Similar research is needed on civil types. The operational research sections consist of scientists under the control of the Service or civil departments, not under the Ministry of Supply, but they are in close touch with the scientists in the laboratories, so that the results of operational experience can be quickly used to improve the aircraft for its service use.

Research in Industry

The research and development facilities at the experimental establishments are supplemented by a considerable effort in industry. It has been the policy of the British Government to place a substantial part of its applied research and development work with industrial firms, where it is in the closest possible touch with design. A number of research aircraft, with little or no likelihood of meeting an operational use, are always under construction. Aircraft firms, in connection with the design of these aircraft, and indeed with operational aircraft also, need to make research investigations, and for this purpose ground equipment, sometimes

A British guided rocket leaving its launching ramp at a Ministry of Supply experimental establishment in South Wales.

elaborate and on a large scale, is provided. In the gas turbine field, in particular, the firms have large and costly ground equipment not only for the testing of complete engines, but also for separate components such as compressors, combustion systems and turbines. It is not practicable for aircraft firms to have very large wind tunnels, but the Society of British Aircraft Constructors are now putting up a cooperative tunnel for the use of all firms. The tunnel will be used mainly for testing actual designs of aircraft.

In electronics a number of industrial research laboratories have been set up. They are engaged in the development of new techniques as well as the design of prototype equipment for both aircraft and guided weapons.

Another view of a rocket being launched at the South Wales site. Booster rockets are at the rear and fall off after the missile has reached its cruising speed.

Results Achieved

The success of a research organization must be judged, in the long run, by the quality of the ultimate product—in this instance by the quality of the military and civil aircraft and guided weapons produced. The latest British jet fighters with swept-back wings, the *Swift* and the *Hunter,* have an all-round performance unsurpassed by any other fighter in the world. They are based on a series of research experiments in which swept-back wings were fitted to standard types, after exhaustive wind tunnel tests. The development of delta-winged aircraft has been undertaken in the same way. Research in wind tunnels was followed by the construction of a number of flying models. This work has culminated in the large Avro delta bomber, the *Vulcan,* the most ambitious large aircraft of this kind yet to fly.

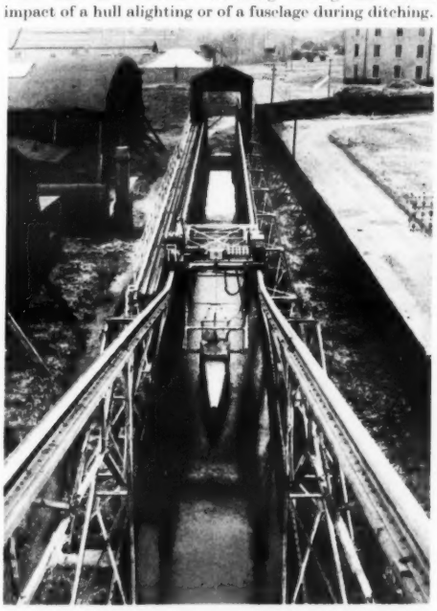
A second approach to the long-range bomber is to use a large aspect ratio. In the design of such aircraft for high subsonic speeds, great skill is required in providing them with the right amount of sweepback along the span so as to give the best range. The Vickers-Armstrong *Valiant* and the Handley-Page *Victor* are based on hundreds of hours of wind tunnel tests at the R.A.E. as well as many smaller scale tests at the parent firms.

These are some of the achievements in the military field in which research has played a major part. In the guided weapons field, the progress made since the end of the war has culminated in the construction of weapons travelling at three times the speed of sound and capable of intercepting a target with great accuracy. This may involve about five times the degree of manoeuvrability of fighter aircraft.

In civil aircraft, the achievements of the de Havilland *Comet,* Vickers *Viscount* and Bristol *Britannia* are well-known. It is not generally appreciated how much the successes are the result of the support, in research and development, given by the experimental establishments. As an example, more than one hundred hours' wind tunnel testing was done on the *Comet* at the R.A.E. alone.

For the future, the new facilities at the National Aeronautical Establishment, in addition to the existing facilities at the Royal Aircraft Establishment, are thought to provide adequate research support for the new types of aircraft, both subsonic and supersonic, likely to arise. In guided weapons the same facilities supplemented by ranges, including the Australian range, fully equipped with electronic and other recording devices, should meet every need. In the electronics field the facilities needed are on a smaller scale. The emphasis here is on the study of basic problems, but the use of electronic simulators on a more and more eleborate scale may be expected. They play the same part, in electronics and instrumental work, that wind tunnels and structural testing frames do in the design of the basic aircraft.

Marine Aircraft Experimental Establishment, Felixstowe: the hull launching tank. The model hull—up to 30-inch beam, or about 1/3rd full scale of an aircraft weighing 70,000 lbs.—is suspended from a carriage which runs down a ramp to attain the required speed and then along a track parallel to the surface of the water. The model was used for determination of pressures and accelerations occurring during the initial impact of a hull alighting or of a fuselage during ditching.



European Research

Aeronautical Research in France

BY MAURICE ROY, MEMBER OF THE INSTITUT DE FRANCE, DIRECTOR OF O.N.E.R.A.

Maurice Roy, head of his class at the Ecole Polytechnique, *has been a member of the Mines Corps since 1922. Engineer and professor, he has specialized in mechanics, thermodynamics, heat machines and power plants. He taught mechanics of aviation at the* Ecole Nationale Supérieure de l'Aéronautique *from 1930 to 1940. A pioneer of jet propulsion, he formulated a general theory of it as early as 1929, foreseeing its practical forms of application. He was elected member of the* Académie des Sciences *(Mechanics Section) in 1949 and is a Member of the Royal Aeronautical Society and Associate Member of the Institute of the Aeronautical Sciences. He was appointed head of the* Office National d'Etudes et de Recherches Aéronautiques *on August 20th, 1949.*

Nobody will deny that research is of vital importance to aeronautical engineering. The aircraft uses the latest advances in the most varied branches of engineering, since scientific development is very closely related to practical achievement.

The history of aviation in all the major industrial countries during the past half century abundantly illustrates this fact. It also shows to what extent the real efficiency of the aircraft, engine and equipment industries depends on a harmonious balance between research, design and production.

The part played by Frenchmen in the early development of modern aviation is well-known. But what is sometimes overlooked is that Frenchmen also carried out considerable basic research, some of which was of decisive importance. Men like Charles Renard and his brother, Ferber, Lafay, working at the *Etablissement d'Aérostation Militaire* of Chalais-Meudon at the dawn of the 20th century, carried out experiments which greatly enlarged fundamental knowledge.

At the same time private individuals, such as Eiffel and Armand de Gramont, were engaged in experimental aerodynamic research, and introduced the first test equipment. After making experiments on air resistance from the tower which bears his name, Gustave Eiffel built one of the first wind tunnels, later copied in several other countries.

About 1928 Albert Caquet gave a fresh impulse to research in France, in particular in the various branches of aeronautics, using both official establishments and university laboratories in close collaboration.

With the constant development of the branches of science which concern aeronautical engineering, however, it became more and more obvious that research should be concentrated under one body, and that this body should be given properly equipped laboratories run by specialists. Admittedly, industry can make up for the lack of such a body up to a point, but the resultant rivalries not only lead to duplication of effort but also prevent complete coverage. Moreover the urgency of immediate needs, which is particularly pressing in the eyes of all industrial management, tend to cause long-range research to be neglected in favour of such partial experiments and tests as are required to solve immediate production problems.

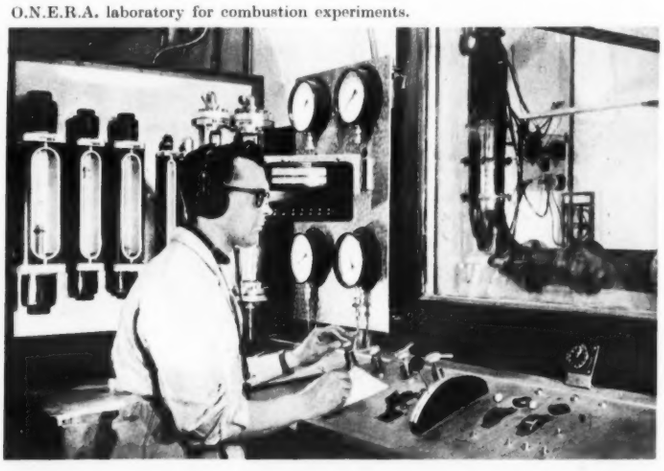
O.N.E.R.A.'s central building at Châtillon.

It was these considerations that led the United States to set up its famous National Advisory Committee for Aeronautics during World War I. The fruits of the continued methodical development of this Committee are well-known.

When World War II came to an end in 1945, it had practically ruined all aeronautical research equipment in France and dealt some very heavy blows at the potential of her aircraft industry.

Measuring vibration on a prototype.

O.N.E.R.A. laboratory for combustion experiments.



Flight Test Centre at Bretigny.

In the general reconstruction of this potential, a new organization was set up for research, namely the *Office National d'Etudes et de Recherches Aéronautiques* (O.N.E.R.A.) under a law of May 3rd, 1946. It was given the surviving government-owned or subsidized facilities that had previously been engaged on aeronautical research. It was also given the task of maintaining contact with other, not specifically aeronautical research organizations, such as the *Centre National des Recherches Scientifiques* and the universities, which can help in the common task of advancing aeronautical engineering on a national level.

Organically, O.N.E.R.A. is a public establishment, with financial autonomy, under the combined charge of the Secretariat of State for Air and the Ministries of Finance and Economic Affairs. It is administered by a Board of Directors comprising representatives of the public services directly concerned.

The Board of Directors and the Managing Director are assisted by a scientific committee responsible for guiding and encouraging research, and a consultative body consisting of representatives of the agencies and industries making use of aeronautical research, who put forward suggestions to meet their needs in the matter of research and development.

Today O.N.E.R.A. employs a staff of roughly 1,700 persons, including a small administrative staff and some 450 engineers, assisted by technicians and highly skilled workers.

Its work falls under five main headings: aerodynamics or mechanics of fluids, energy and propulsion, materials, structural strength and general physics, which also comes into the four other fields.

However, O.N.E.R.A. is far from being able to cover the whole vast field open to research in these subjects, despite their undisputed importance. Its programme, continually revised in the light of recognized needs, the objects to be pursued and the resources available, is therefore dominated by the necessity of concentrating these resources on major objectives and making a sustained effort in the directions selected.

For example, O.N.E.R.A.'s energy and propulsion section does not engage in general research into fuels and lubricants, but has an understanding with the French Petroleum Institute for the latter to include this work in its own programme.

Similarly, where materials are concerned, O.N.E.R.A. could not even think of embracing the whole field of metallurgical research. It therefore collaborates with specialized organizations such as I.R.S.I.D. and Professor Chaudron's laboratory, and with private industrial laboratories, and limits its own efforts in this direction to special research and purely aeronautical applications which other organizations would not undertake.

Again, in general physics, O.N.E.R.A. could in principle investigate innumerable problems, from physics of the atmosphere at all altitudes and in all conditions to the most varied applications of radio-electric waves, magnetism, infra-red rays, optics, etc.... In practice—and this is already a wide enough field of activity—this department devotes itself above all to supplying the needs of the other departments for observation, measuring, recording and remote-control equipment.

Today O.N.E.R.A.'s equipment programme, progressively adapted to continuous revisions in the research programme, is well on the way to completion.

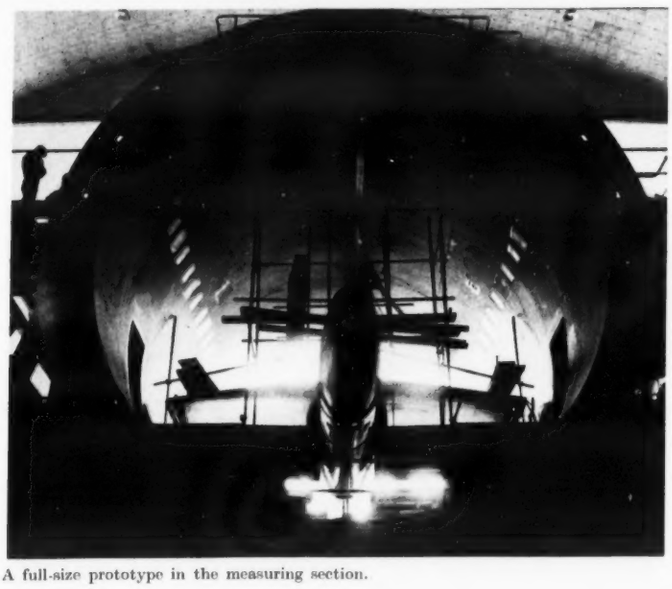
The Office's main facilities are at Châtillon and employ nearly 1,000 persons. Here are scientific managements and the majority of the light laboratories. The central establishment is almost fully equipped and has been in full operation for at least two years.

The Chalais-Meudon plant is on the same site where the earlier research work was carried out. It contains in particular the large 79×39.5 ft. subsonic wind tunnel, built in 1929 and still in service today, a sonic wind tunnel—soon to be supersonic—with circular flow 39.4 ins. in diameter, a medium-size supersonic wind tunnel

Part of the big Modane-Avrieux high-speed tunnel (area 213 ft. × 574 ft. diameter of flow 26.2 ft.; max. speed approximately 670 m.p.h.)

View of the Modane-Avrieux turbine hall: two Pelton water turbines of 55,000 h.p. each drive the tunnel's rotary blower via huge shafts.

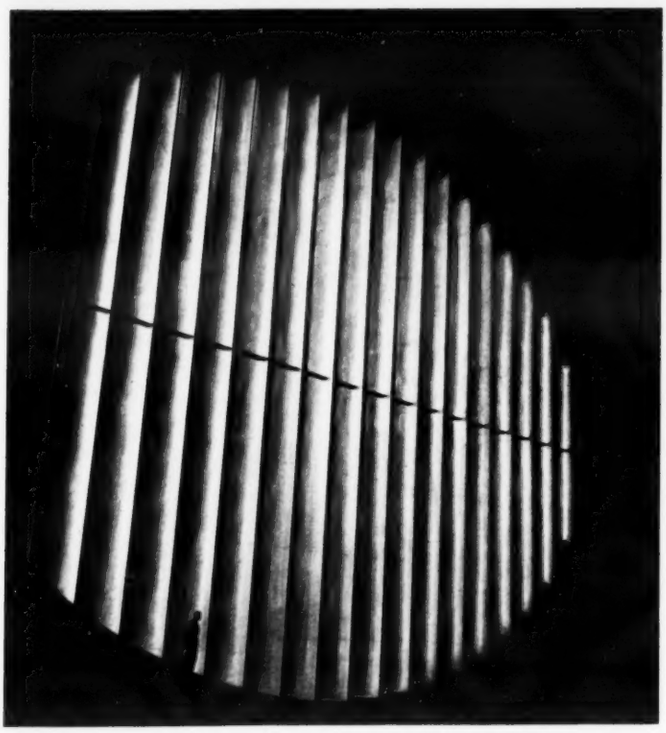
Each of the two blowers at Modane-Avrieux is 52.5 ft. in diameter.



A full-size prototype in the measuring section.

capable of operating at up to Mach 3, and a number of small or special wind tunnels, a combustion laboratory and various other installations.

The Modane-Avrieux establishment, started in 1946, now contains the well-known 110,000 h.p. sonic wind tunnel, with circular flow 26.2 ft. in diameter, powered by hydraulic turbines driving two fans 52.5 ft. in diameter. The tunnel is now being completed, although it has been in operation for nearly a year. A supersonic tunnel, using the same hydraulic source of power and capable of reaching Mach 2, is under construction and will form a valuable addition to the existing one. The whole will make up a research and test centre unique in Europe and will be able to satisfy the needs of a number of other countries, either in Europe or across the Atlantic.



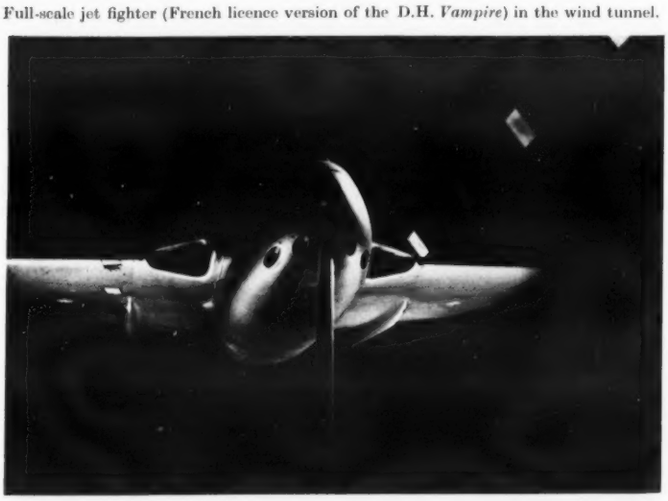
At the four corners of the tunnel the air flow is diverted through 90° by giant vanes.

The Palaiseau facility, using in part the site and installations of an old fort on the outskirts of Paris, is devoted primarily to power plant and propulsion research. Its equipment is not yet complete, but is being added to constantly, so that it will complement the fine industrial and technical test installations for all kinds of power plant that have been erected at Saclay and Villaroche during recent years.

O.N.E.R.A. has a number of other minor establishments at Cannes, Algiers and Le Bouchet (the latter being gradually absorbed into Châtillon).

The equipping of all these facilities still takes up a substantial part of O.N.E.R.A.'s technical activity. When completed, the whole facilities, though modest in comparison with certain establishments in other countries, will nevertheless be reasonably well adapted to the requirements of present-day aeronautical research.

Full-scale jet fighter (French licence version of the D.H. *Vampire*) in the wind tunnel.



German Aeronautical Research Seeks New Roads

BY PROFESSOR DR. PHIL. DIPL.-ING. ALBERT BETZ,

HEAD OF THE MAX PLANCK INSTITUTE FOR FLUIDS RESEARCH, GÖTTINGEN

At this year's meeting of the German Society for the Aeronautical Sciences (Wissenschaftliche Gesellschaft für Luftfahrt), held at Göttingen on May 27th and 28th, 1953, and attended by a large number of scientists from Germany and abroad, the principal lecture was read by Professor A. Betz. After Professor Ludwig Prandtl, Betz is undoubtedly the most prominent representative of the Göttingen School of aerodynamics and is one of the founders of modern wing theory. He gave an outline of the prospects for Germany's taking an active part again, despite limited resources, in aeronautical research. The following is an extract from this lecture.

EDITORS

At the 1939 Lilienthal Congress in Munich I demonstrated with the aid of a diagram that the power of wind tunnels is multiplied roughly tenfold every ten years. I emphasized that this development could not continue indefinitely and that we must look around for other means of research. Today wind tunnels have already reached powers of several hundred thousand horse power.

This trend of development is not confined to wind tunnels, but can be observed in many technical fields. When steam engines and other machines replacing and amplifying human labour were introduced, the advantage of making machines as big as possible was soon realized. It almost looked as if there were no limits. Of recent years, however, there have been increasing signs that size, speed and automatic operation cannot be increased indefinitely. Limits are appearing, some imposed by the nature of materials, some by the nature of man.

In aviation these difficulties first arise in the military air arm. However, what applies to combat aircraft today will apply to civil aviation tomorrow. The supply of many special materials is already proving difficult. Above all, man himself ultimately is found incapable of piloting these advanced types of aircraft. The burden on him must be lightened by automatic controls, the costs of which may frequently become prohibitive. In *Interavia Review* [1] I recently read an article by General *Chassin* on the war in Indochina: he states that in Indochina highly-developed modern aircraft are useless, and only relatively simple machines which make few demands on aircrews or ground organization are of value. He even writes that we must decide now whether to continue on the present road to highly complex aircraft or to turn back to simpler equipment. Personally I cannot entirely agree with this view. I believe that we need both aircraft of the highest technical efficiency *and* more primitive equipment.

Today we find in research a kind of "mass production" of results which, like the achievements made throughout engineering, is obtained at terrific expense in men and equipment. This mass production is quite essential and sometimes produces very valuable results. But the very fact that *Prandtl* recognized the importance of the boundary layer from very primitive experiments and thus took a step forward which in itself is of the same magnitude as the results of mass research, should make us stop and think. Similar revolutionary advances by particularly gifted scientists can also be found in other fields. I need only recall *Einstein's* theory of relativity, *Planck's* quantum theory or *Hahn's* discovery of atomic energy.

We cannot do without large-scale research, but it does bring with it the danger that the perhaps more important work of especially gifted individuals may be rendered more difficult, if not impossible. We researchers must therefore also seriously reflect on what could be done to master these difficulties.

*

One of the most urgent tasks in all countries is to reduce the load on the big wind tunnels. We cannot do without them entirely, but must try to manage with the minimum of such giant installations, as it may be that the vast power they will require in future can only be provided by big atomic centres. International cooperation is therefore more essential than ever. But new methods of research must also be followed.

I pointed out this necessity as long as sixteen years ago and suggested that greater use should be made of flight tests—in particular by gliders—and of theoretical calculations. Much has since been done in both these directions. In Germany glider research was carried to a high level by the DFS (Deutsche Forschungsanstalt für Segelflug = German Glider Research Institute) under *Georgii*. And I recently heard a lecture by *Raspet* who is also following quite new methods in America to make the glider into an efficient research instrument. However, a greater number of gifted people should devote themselves to these tasks. I was therefore very glad to see that the model builders have offered to place their highly advanced techniques at the service of research, and that the WGL is to support these efforts. One method which seems to me to be very promising was developed at Brunswick during the war. It consisted of launching model aircraft by rockets and investigating their behaviour in flight.

Theoretical work has greatly increased and has produced not only extensive but also practical results. But my impression is that these results in general have not yet reduced the strain on large research installations, but have been carried through alongside these experiments. What is needed is an effort to replace experiments by calculations. Examining the subsonic qualities of an airfoil in a wind tunnel must today already be regarded as unnecessary. These qualities can be calculated theoretically much more reliably—and for any Reynolds number. Admittedly such calculations are not exactly simple. One very important task, therefore, is to find some way of simplifying them so that they can be completed easily and rapidly. A great many examples must be checked to discover what is essential and what secondary in such calculations, and the functions used regularly should perhaps be tabulated. *Riegels* has been working in this direction for some time. Extension to flows through cascades has been well advanced by *Schlichting*, and there is an excellent book on propellers by *Theodorsen* [2] which goes far towards meeting the above requirements.

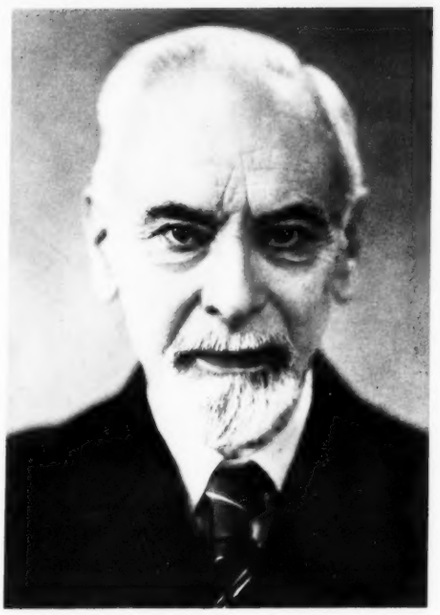
It seems to me that calculations can be based, for example, on flow round simple-shaped slender fuselage models, since it is already possible to deal with bodies with other than

[1] G. J. M. Chassin: "Lessons of the War in Indochina," *Interavia*, Vol. VII, No. 12, p. 670.

[2] Th. Theodorsen: "Theory of Propellers," McGraw Hill, New York, 1948.

circular sections. In the majority of such tasks, the potential flow is first calculated, without allowance for boundary layer, then the boundary layer itself, on the basis of the pressure distribution obtained. *Schlichting's*[3] book is of great help here. If necessary, the process must be repeated, with allowance for the change in pressure distribution due to the displacement thickness of the boundary layer.

Rapidly increasing flying speeds have brought high-speed research to the fore, and this is now being carried out intensively everywhere. Processes that are clearly subsonic or supersonic can be largely calculated. The greatest difficulties are experienced in the neighbourhood of sonic speed, although even here much preparatory work has already been done. A new complex of aerodynamic problems has arisen through the development of modern power plant, in which tremendous masses of air are utilized, with attendant difficulties in the design of intakes and guiding arrangements. These problems were successfully tackled during the war by *Küchemann* and *Weber*, and it is very gratifying that the resulting important theories have recently been collected in handy form.[4]



Professor Dr. Ludwig Prandtl, past master of German aeronautical science, built the first return-flow wind tunnel at Göttingen in 1907.

There are many other domains in which it would be very useful to have existing knowledge collated for easy reference. Gaps in theory or experiment often have to be filled in by special investigations, values tabulated or converted into graphs, to round off a subject so that it can be used in practice without exorbitant expense.

*

Germany today is not a rich country. The material resources with which we can build up an aeronautical research organization are now very limited. Furthermore, we must catch up with the great progress made abroad in the past few years. The gap of eight years cannot be bridged without effort. However, even with modest resources and despite long inactivity, we can achieve noteworthy successes if we apply ourselves to certain special fields. What is most important is to attract capable men and women, give them working facilities and remove obstacles from their path. Gifted men will always be urgently needed in German aeronautical research, regardless of the size of the future German aircraft industry.

[3] H. Schlichting: "Grenzschicht-Theorie" (Boundary Layer Theory), Braun, Karlsruhe, 1951.

[4] D. Kuchemann and J. Weber: "Aerodynamics of Propulsion," McGraw Hill, New York, 1953.

A New Start for German Research

It may perhaps be said that German aeronautical research did not achieve world-wide recognition until its death-knell was sounded in 1945. When its legacy—research reports, research facilities and scientists—had been distributed, it became clear that the German research establishments had made some extremely valuable contributions to the progress of aviation.

Thus, when the political developments of recent years made it appear likely that German aviation would be revived, the problem of research was also taken up again. Today, in 1953, a modest basis on which pursuit of the aeronautical sciences can be resumed is already available in Western Germany, though full freedom of research will, of course, not be achieved until the Bonn Treaty enters into force.

The reason why such early attention is being paid to aeronautical research (before it is known if or when a German aircraft industry will be called to life again) may be that it forms a very important part of scientific research in general. No economy based on engineering—as is Western Germany's—can do without it, without suffering in its ability to compete both at home and abroad. Even if there were no reason to resume aircraft and engine production one day, the pursuit of aeronautical research would be essential to the West German Republic, as its economy must stand or fall by creative research. Recognizing this fact, the Federal Transport Ministry and the German Research Association, and above all Prof. *Brandt* (of North Rhine-Westphalia's Ministry of Economics and Transport) and Prof. *Seewald* (of Aachen Technical University) have worked hard for the resuscitation of aeronautical research.

After the German research establishments had been dissolved or dismantled, there remained seven institutes, some of them still with ground and buildings, but completely without research equipment. They include the *Aerodynamische Versuchsanstalt* (Aerodynamic Research Institute) at Göttingen, the *Deutsche Versuchsanstalt für Luftfahrt* (German Aeronautical Research Establishment) and one or two university institutes, for example the Aerodynamic Institute at the Technical University, Aachen.

The DVL, having lost its installations at Adlershof, Berlin, was scarcely more than a name with a great past. At first there was considerable difference of opinion as to whether it should be reactivated or not. The Federal Transport Ministry then saw no need for it, as such an establishment presupposes the existence of an aircraft industry. This attitude has now changed.

On the other hand North Rhine-Westphalia urged the re-establishment of the DVL from the beginning, partly because a number of former heads of the DVL are working as professors and heads of institutes at the Aachen Technical University: Dr. Ing. *Seewald* (Aerodynamic Institute); Dr. Ing. *Leist* (turbo engines); Dr. Ing. *Bollenrath* (Materials Institute): Dr. Ing. *F. A. F. Schmidt* (Machine Design Institute). These men formed working groups and later founded three institutes towards the new DVL. The High Frequency Institute, headed by Prof. *Esau*, and the Thermodynamics and Fuel Research Institute, under Prof. *Schmidt*, were set up in Essen (where there was an airport available); the Aeronautical Medical Institute was founded in Bonn, under Dr. Ruff. North Rhine-Westphalia has so far spent roughly two and a half million Marks on the activation of these institutes and on research work in general.

Other funds to promote research—a million and a half Marks during the current financial year—have been provided by the Federal Transport Ministry. The Federal Ministry of the Interior has also put up DM 2,000,000 through the German Research Association. Federal Transport Ministry funds are to be used primarily for applied research, whereas the monies administered by the German Research Association are to be spent on basic research.

All this is barely more than a modest beginning. But it is the first step towards practical aviation activity in the Federal Republic after eight years' enforced inactivity. *R.W.S.*

What the Smaller Nations are doing

In many respects the smaller nations are handicapped by their size when they try to keep pace with the great powers in numerous fields of engineering research, particularly in aeronautics, because of the large amounts of money involved. On the other hand, small size has its advantages. In aeronautics, for example, smaller countries can use their resources in a concentrated effort in basic research to extend their overall aeronautical horizon, and some of them, especially Switzerland, have attained leading positions in certain sectors of research. Furthermore, the research institutes can place themselves at the disposal of one or two national manufacturers who thus have fewer worries than the numerous manufacturers in the larger countries as to how they should persuade the perpetually overloaded research institutes to take care of their problems quickly. Cases in point are Sweden and Holland, whose air research resources can concentrate almost entirely on problems encountered by Svenska Aeroplan A.B. and the Fokker Aircraft Company, respectively. Both these countries have long been famous for the high quality of the aircraft turned out by their relatively small industries.

Sweden

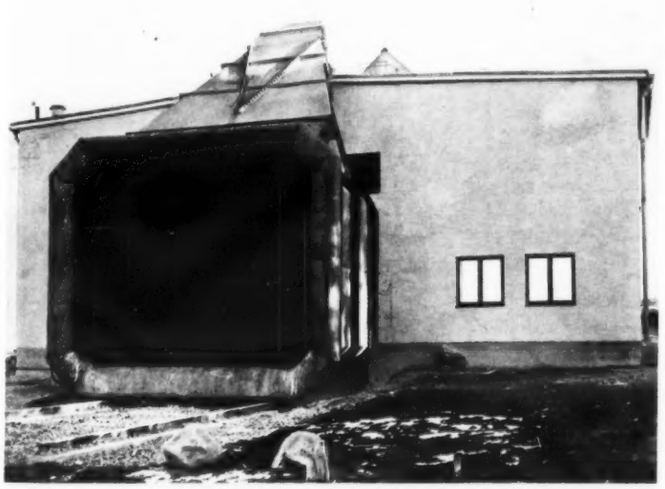
Swedish aeronautical research is the responsibility of *Flygtekniska Försöksanstalten* (F.F.A. = Aeronautical Research Institute) at Ulvsunda, near Stockholm, and *Kungl. Tekniska Högskolan* (K.T.H. = Royal Institute of Technology) of Stockholm. The former, with its modern equipment and highly qualified staff, is almost entirely at the disposal of S.A.A.B. for the solution of design problems; the latter, though it also assists S.A.A.B. with its supersonic wind tunnel, concentrates on providing advanced aeronautical engineering training for Sweden's youth. Finally, S.A.A.B. is doing a certain amount of research on its own and has developed a transonic wind tunnel. Of unique design, it is worked by four jet engines forcing the air through the test section. It can be used for studies at speeds of up to Mach 1.5.

F.F.A. is expected to put two new supersonic wind tunnels into operation in 1954. So far, the institute's high-speed research facilities have comprised a subsonic continuous-type wind tunnel of 10.8 sq.ft. test cross section, with a limiting Mach number of .92. There are also a few small intermittent supersonic tunnels, the larger of which has a test section of only 9.5 in. by 12 in. These small tunnels are suitable only for certain basic research at up to Mach 4.0. The 10.8 sq.ft. continuous tunnel has recently been modified (power increase from 1,500 to 3,000 h.p.), and its performance improved.

Construction of the two new supersonic tunnels was authorized by the 1950 Parliament. Both will be of the intermittent type, and the larger one will have a test section of 10.8 sq.ft.; the test section of the smaller one will be 2.7 sq.ft. Both tunnels will be operated on the vacuum principle with two underground chambers, hewn from the rock, one of 282,520 cu.ft. and the other of 70,630 cu.ft. There will be a 1,350 h.p. pumping station, laboratories, workshop and office buildings. Designed for studies at up to Mach 4.0, both tunnels can also be used for subsonic tests. Maximum operating time between pumping periods is 30 seconds on the large tunnel and two minutes for the smaller one. Pumping periods vary up to 18 minutes for the larger facility, depending upon the Mach number required. The two tunnels are estimated to cost Sw. kr. 11,330,000.

The two installations will mark the completion of the initial phase of Sweden's

The air intake of the wind tunnel at S.A.A.B. Aircraft's plant at Linköping, Sweden, is mounted on rails to permit its removal for full-scale jet aircraft air intake and rocket research.



The S.A.A.B.-210 *Draken* "double-delta" research aircraft is believed to be the forerunner of a Swedish supersonic fighter.

aeronautical research expansion programme recommended in 1949 by the Parliamentary Air Research Committee formed in 1947.

Further Expansion

In 1951 the Committee submitted a proposal to the Government for a second expansion phase at F.F.A., including the construction of a *new transonic wind tunnel installation,* but Parliamentary approval is still pending. The proposal provided for two new wind tunnels, both intented for the "subsonic and supersonic transonic" speed regions. One would be a 10.8 sq.ft. continuous-type closed-circuit tunnel with a 15,000 h.p. power source, the second a 32.4 sq.ft. intermittent type non-return flow facility using a 600,350 cu.ft. underground chamber more than 600 ft. below the surface. Both tunnels would be used for tests at up to Mach 1.5.

The cost of the second F.F.A. research expansion programme was originally estimated at Sw. kr. 27.700,000, but price increases have raised the total to more than kr. 35,000,000. This expenditure seems to be well justified, however, since the planned facilities will add tremendously to Sweden's ability to keep her aircraft industry in the van of aeronautical progress, an imperative necessity in view of the country's traditional neutrality.

During the 1953 fiscal year the F.F.A. will increase its staff from the present 151 to 209 to handle the new supersonic wind tunnels when they are completed. With the new facilities, the Institute expects to increase its activity by 40 percent.

Its operations are expected to cost the Swedish Government kr. 3,445,000 in fiscal 1953-54, and it will also receive kr. 2,285,000 for research contracts carried out for the aircraft industry and for guided missiles and projectile research.

One unusual feature of the existing and planned F.F.A. research facilities will be the possibility of combining their various vacuum underground chambers, so that the construction of wind tunnels for investigations at up to Mach 7.0 would be feasible.

Aero engine and aeromedical research

Swedish aero engine research received a heavy blow last year when the Air Force cancelled its contract for the development of the STAL *Dovern* axial jet (7,300 lbs. s.t.) and the STAL *Glan* two-spool jet (11,000 lbs. s.t.) and replaced the programme with a contract for the manufacture of Rolls-Royce turbojets under licence. In connection with the original programme, *Svenska Flygmotor,* of Trollhättan, the country's oldest engine maker, who had been cooperating with *Svenska Turbinfabriks Aktiebolaget Ljungstrom* in the development of the STAL engines, had invested heavily in the construction of a super-modern jet-engine laboratory using a "wet" underground chamber for air supply. It is now expected to be used to some extent to investigate problems arising out of the manufacture of the British engines.

Other aviation research under way in Sweden includes an *aeromedical research programme* which is now being greatly expanded. At the Karolinska Institute, Stockholm, a Flight Physiological Institute is now being established and is scheduled for completion in the autumn. As Sweden's most important aeromedical installation, it will include a human centrifuge, the first modern device of the kind in Europe—and a low-pressure chamber simulating altitudes up to 72,000 ft., as well as other aeromedical laboratory equipment. Other low-pressure chambers and related equipment are already available at Gymnastiska Centralinstitutet (GCI), Stockholm, and at the Universities of Lund and Uppsala, as well as in the Air Force. In the newly completed altitude and temperature chamber at Uppsala University, altitudes up to 82,000 ft. can be simulated, while the pressure chambers at Lund will ultimately "reach" 98,000 ft.

HANS G. ANDERSSON, LINKÖPING

Switzerland

The centre of Switzerland's aerodynamic research is the *Aerodynamics Division of the Swiss Federal Institute of Technology* at Zurich, headed since its creation in 1931 by Professor Dr. J. Ackeret. The Division has a return-type wind tunnel (measuring section, 6.9 ft. by 9.8 ft.) for speeds up to 185 m.p.h. A six-component balance enables tests to be made with aircraft and wing models in both the open air flow and the enclosed measuring section. The power of the two driving motors is 550 h.p.

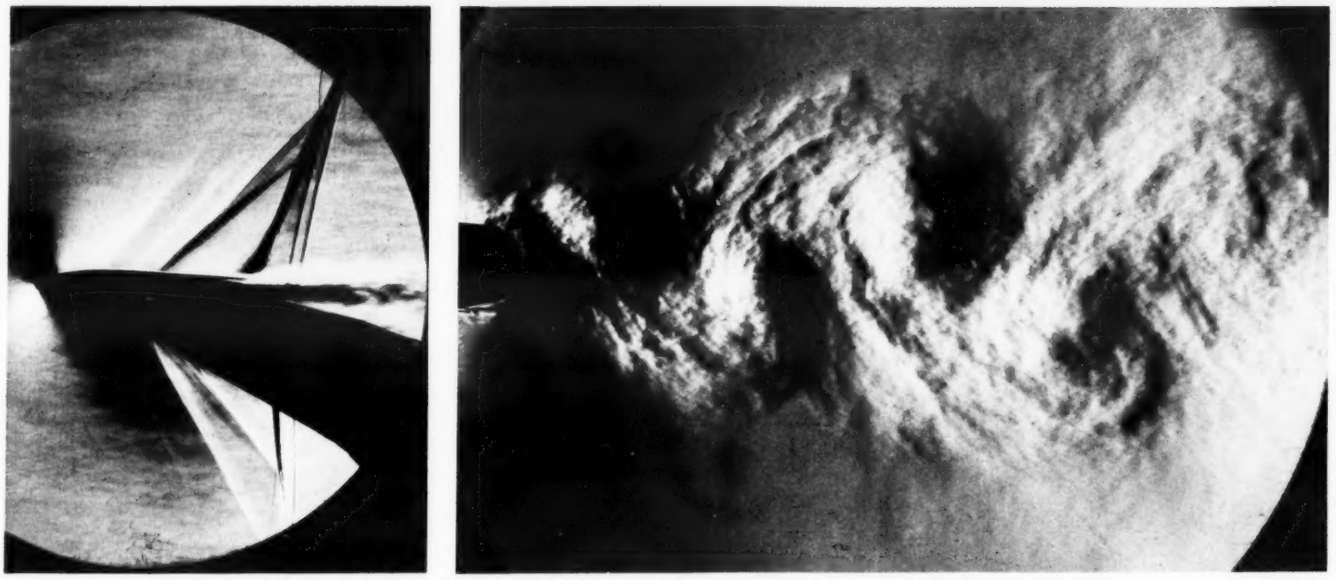
A smaller, non-return type wind tunnel, with a 45 h.p. power source, serves chiefly for cascade flow research and for measurements on axial flow blower stages, as well as wind pressure studies on model buildings (in open flow). Finally, there is a low-turbulence calibrating tunnel for measuring instruments (power : 250 h.p.) with air speeds up to 370 m.p.h.

As long ago as 1933 a high-velocity and supersonic tunnel was built to the plans of Professor Ackeret. This, the world's first closed-circuit supersonic wind tunnel, attained double the speed of sound in the measuring section (15.7 in. by 15.7 in.) with a power source of 900 h.p. The advantage of the tunnel is that the air flow can be evacuated to different degrees of decompression. By varying the pressure level the Reynolds number can thus be changed independently of the Mach number. For flow photographs there is a stria camera with continuous and flash illumination ; an interferometer is under construction.

The working methods of the Division aim chiefly at perfecting theory by adaptation to new knowledge gained *experimentally.* In this manner it has repeatedly been able to contribute new knowledge in the field of aerodynamics : experiments with cascades and axial blowers ; boundary-layer control ; investigation of compressible flows at high subsonic speeds (among other points : compressibility effects and temperature effects in the case of vortex separation) ; supersonic measurements, chiefly on plate grids.—On the basis of wind pressure tests on model building structures new standardized wind resistance requirements have recently been established for Switzerland.

Work now in progress is concerned, in the field of *fluid flow machines,* with a further expansion of the cascade-flow and blower tests in the subsonic and supersonic regions and with measurements on baffles and diffusors. In the field of *aeronautical engineering,* tests are under way on delta wings at low speeds, as well as the development of a thrust brake employing jet deviation on turbojet-powered aircraft. In *aero-thermodynamics* work is going on to determine the temperature effects in compressible vortex fields and on experiments with vortex and resonance tubes.

Liaison with international research is logical owing to the topical character of the work in progress. For example, the boundary-layer control tests carried out by Dr. W. Pfenninger, Dr. A. Gerber and Dr. M. Ras, the investigations into compressibility influence and compressibility shocks made by Dr. J. Ackeret, Dr. F. Feldmann, Dr. N. Rott and M. Degen, finally the work on axial blowers by Dr. C. Keller and on the application of gas-dynamic methods to currents with free water surfaces were of a fundamental nature at the time. The



Left : Air flow at Mach 0.8 on a NACA 0012-1.1-30 aerofoil : shock waves and boundary layer break-away are clearly visible ; the lower contour of the aerofoil and part of the flow are hidden by the model support. (Stria photo with flash illumination from the supersonic and high-speed tunnel at the Aerodynamics Division, Zurich). *Right :* Stria photograph of Kármán's vortex street behind a circular cylinder. (Photo : Aerodynamics Division, Zurich.)

present working programme, too, is designed to contribute to the solution of "international" problems.

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Switzerland's second large aerodynamic experimental establishment consists of the wind tunnel installations of the *Swiss Federal Aircraft Factory* at Emmen, which is controlled by the Military Engineering Division *(Kriegstechnische Abteilung)* of the Defence Department, Berne. Work was started on the facility in 1944 and completed in 1947 ; the installation is directed by Dipl. Ing. W. Hausammann and serves chiefly for applied research, i.e., aeronautical development engineering work on airframes and engines.

The Emmen facility comprises two closed-circuit wind tunnels, a spinning tunnel and a transonic tunnel. The big tunnel (measuring section 19.7 ft. by 26.2 ft.; air speeds up to 180 m.p.h.), with a power source of 3,900 h.p., is Switzerland's largest tunnel. With a fully automatic six-component balance (two control surface forces can be measured in addition) and special suspension (electric wiring to provide current for two motors driving model propellers), the tunnel can be used with an open or an enclosed measuring section.

The small tunnel (315 h.p.; measuring section 8 ft. by 5.7 ft.; speeds up to 140 m.p.h.) is operated exclusively with an open section. The elbow baffle ahead of the measuring section can be turned, so that the air flow from the blower is turned upwards into the spinning tunnel. Both tunnels are thus fed by the same blower, but the air flow in the vertical tunnel escapes into the outside atmosphere (diameter, 32.8 ft.; speed, about 65 m.p.h.). The new transonic tunnel operates with the suction of two Rolls-Royce "Nene" jet engines (measuring section 20 in. by 24 in.).

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Aeronautical engineering research is also carried on by *Flug- und Fahrzeugwerke Altenrhein* (formerly Dornier-Altenrhein), whose aerodynamics section has been much expanded in the past few years. Under the supervision of Dr. H. L. Studer a start has been made on the design of a jet fighter type. Extensive aerodynamics research is also undertaken under the direction of Dr. A. Berger, by *Oerlikon Machine Tool Works Bührle & Co.,* near Zurich, for the development of a guided anti-aircraft missile and smaller solid-fuel rockets. The supersonic wind tunnel at the Aerodynamics Division of the Federal Institute of Technology and the smaller tunnel at Emmen are available for this purpose.

Finally, most of Switzerland's larger engineering firms have their own flow laboratories : *Escher-Wyss AG.*, Zurich (under Dr. C. Keller) ; *Sulzer,* Winterthur (under Dr. P. de Haller) ; *Charmilles,* Geneva (under Dipl. Ing. M. Fauconnet) ; *Brown, Boveri & Co.,* Baden. This industrial research enables Swiss manufacturers to keep abreast of progress abroad in the design of fluid flow machines. The development of gas turbines has been the object of particular attention. This has resulted, for example, in the construction of the "Ackeret-Keller" closed-circuit turbine. As long ago as 1937 Escher-Wyss used an *aerodynamic* test bench for water turbines and carried out tests in the wind tunnel of the Institute of Technology on a controllable-pitch ship's propeller. The same company brought out an efficient reversible-pitch braking airscrew in 1938.[1]

Today Switzerland possesses a team of aerodynamicists of international calibre. Although a considerable number of Swiss engineers continue to emigrate, the Swiss training institutes are able to provide the scientists required by the country's own industry. If one disregards certain types of research—such as the investigation of full-scale aircraft in very large tunnels, which would be too costly for a small country—one is justified in stating that the country is fully capable of coping with modern aerodynamic research.

Chief credit must be given to Professor J. Ackeret for having raised aerodynamics in Switzerland to a high level of science. Almost every engineer active in Swiss aeronautics today has passed through his school. The Professor is to be congratulated that in his efforts to expand the necessary research facilities he could count upon the comprehension of the authorities, especially of the Council of Education and the Military Engineering Division. New tasks are facing us today, and aerodynamics in particular will offer a field of intensive research for a long time to come.

K. ISSERLAND, ZURICH

[1] That instrument engineering has been greatly stimulated by the expansion of scientific research is shown by the development at the Aerodynamics Division of hot-wire instruments, improved models of which are manufactured in Switzerland today for use by scientific institutes.

European Research

Netherlands

Practically all aviation research in the Netherlands is carried out by the *Nationaal Luchtvaart Laboratorium*, the Dutch National Aeronautical Research Institute, in close relationship and cooperation with the *Fokker Aircraft Company*. Though the present situation in the Dutch aircraft industry does not greatly stimulate aeronautical research in general, since existing and anticipated N.A.T.O. aircraft contracts call for the production of foreign aircraft under licence rather than models of original design, Dutch aviation research has made much progress in the years since the end of the war.

Fokker Aircraft Company

One of the most important research activities pursued at present by Fokkers is the research into the application of metal-to-metal bonding in all-metal aircraft construction. Test results obtained in cooperation with the National Aeronautical Research Institute with plastics-bonded panels and spar booms are expected to lead to completely new applications of the bonding technique, resulting in lower airframe weights and manufacturing costs. In future all Fokker aircraft will use extensive metal-to-metal bonding. The Fokker S.11 trainers to be built will have a fully bonded wing structure, based on extensive tests with an S.11 trial wing.

In the course of these tests, Fokkers developed a variety of test equipment, including the Fokker Roller Strain Gauge with potentiometer transmission to determine the strain in aircraft components, a languet frequency meter with electrical transmission to determine vibration characteristics etc.

National Aeronautical Research Institute

The *Nationaal Luchtvaart Laboratorium* was founded in 1919 as a Government service for aeronautical research and in 1937 was converted into an independent organization. Its aim is to assist civil and military operators in solving problems arising out of aircraft operation. Today 35 graduates of engineering colleges and 80 other technicians are engaged on theoretical and experimental research work at the Institute.

Two subsonic wind tunnels are at present in operation. One has a test section of 4.9 ft. by 4.9 ft., the other of 6.6 ft. by 9.8 ft., in which air speeds of up to 100 m.p.h. and 178 m.p.h. respectively are attained. The smaller one is powered by a 60 h.p. motor, the larger by one of 650 h.p. A third, small supersonic research tunnel (test section 1.2 in. by 1.2 in.) for speeds up to Mach 4 also serves as a pilot installation for a much larger supersonic wind tunnel to be built later on.

Three modern high-speed tunnels are under construction at present. The largest will be a variable-pressure (1/8th to 4 atmospheres abs.) low-turbulence transonic tunnel with a test section of 5.9 ft. by 5.9 ft. The motor will deliver 20,000 h.p., providing air speeds of up to Mach 1.3. The second tunnel—test section 31.5 ins. by 12.6 ins.—will be powered by a 1,200 h.p. motor and used for smaller models at air speeds up to Mach .95. The third tunnel, for investigations from Mach 1.2 to 3.75, will operate with a 6,500 h.p. motor and have a test section of 15.7 ins. by 15.7 ins.

Apart from general and ad hoc aerodynamic research in the widest sense, including research on smoke stacks to diminish the smoke nuisance, wind pressure effects on buildings, etc., the Institute undertakes flight research and prototype testing. Finally, it carries out all structural and material tests for which a test rig, a compression machine, creep machines or hydraulic pulsating machines (for fatigue tests) are required.

Finally, mention should be made of the *Nederlandse Instituut voor Vliegtuigontwikkeling* (Netherlands Institute for Aircraft Development), which more or less is a coordinating and supervisory body of the Dutch Government, the aircraft industry and the Aeronautical Research Institute. It is financed by the Government. HENK A. JANSEN, AMSTERDAM

Front view of the Dutch National Aeronautical Research Institute, Amsterdam. Extreme right : stacks from the power station, where electric power is generated by steam turbines.

Spain

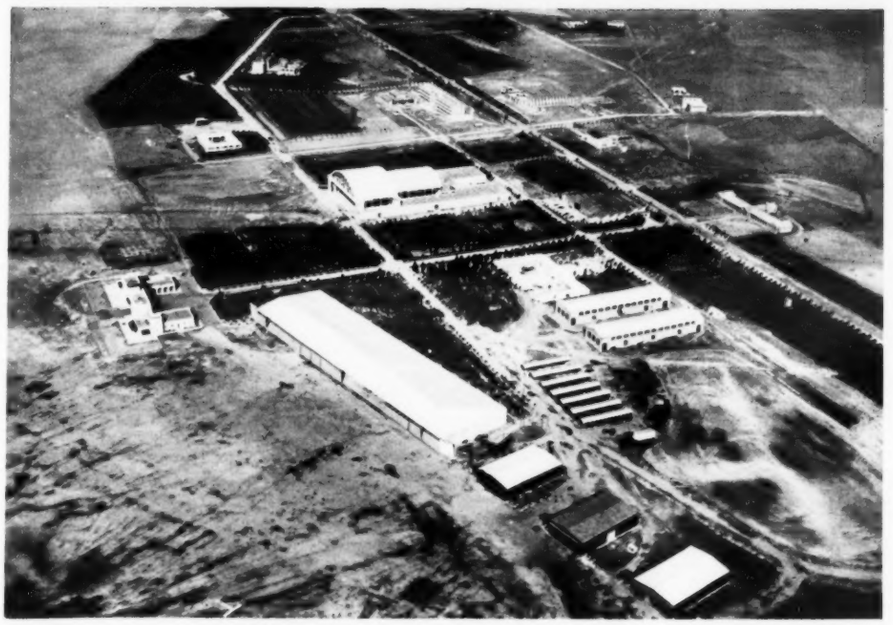
Spain has been interested in aeronautical development from the early beginnings. The first Spanish-designed and built aircraft dates back to 1909. Not much later a return-type wind tunnel was built, and this remained in operation until quite recently. It was situated in the vicinity of Madrid, close to the airfield of *Cuatro Vientos*, where many years later (in 1923) Juan de la Cierva's autogiro made its first flights.

National Institute of Aeronautical Engineering

In 1939, when the Spanish Air Ministry was created, a special Research and Experimental Section *(Sección de Estudios y Experiencias)* was established within it, and in 1942, in order to expand and stimulate aeronautical research, the National Institute of Aeronautical Engineering *(Instituto Nacional de Técnica Aeronáutica,* I.N.T.A.) was set up. The duties assigned to it were "the promotion of aeronautical research and investigation, the creation of conditions propitious to aeronautical science and invention, and the development for practical use, by means of experimentation, of any new theoretical conception in the field of aeronautics . . . "

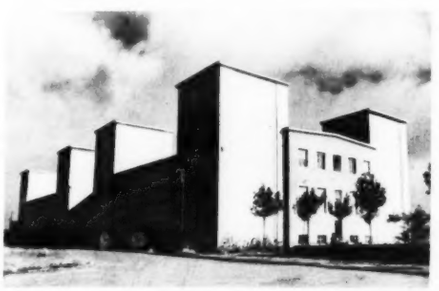
Founded at a moment of crisis in Spanish aeronautical engineering and at a time when World War II severely hampered not only the exchange of technical and scientific information with other countries but also the acquisition of the equipment necessary for its laboratories, the Institute encountered great difficulties from the beginning in its efforts to fulfil its mission of advising and assisting the national authorities and aircraft industry in solving their most pressing problems ; testing the new prototypes ; negotiating for the completion and improvement of its laboratories, in order to adapt them as closely as possible to the new technical development trends.

The *Instituto Nacional de Técnica Aeronáutica "Esteban Terradas"*—the latter name has been adopted in honour of its first President, the eminent scientist Esteban Terrada, who was killed in 1950—is an autonomous organization responsible directly to the Air Ministry. Structurally it is divided as follows : a top Council of Governors *(Patronato Rector)* which guides and encourages the activities of the Institute ; an Executive Committee ; a Director-General ; a General and Technical Secretariat ; an Administrative Secretariat ; and four Scientific and Engineering Divisions, namely, (1) Aerodynamics, (2) Propulsion, (3) Equipment and Armament, and (4) Construction Materials. The Divisions are sub-divided into Sections and the latter into Laboratories. Finally, the Institute has a Standardization Section, a few general workshops and an Experimental Flying Unit.



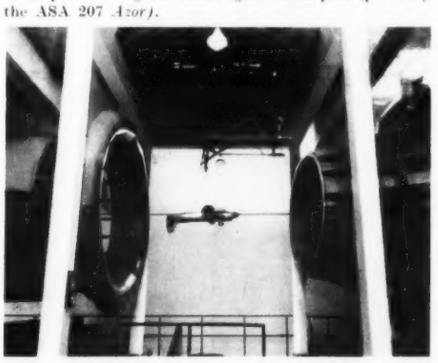
Part of the establishment of the *Instituto Nacional de Técnica Aeronáutica "Esteban Terradas"* at Torrejon de Ardoz, 15 miles from Madrid.

I.N.T.A.'s facilities are situated near the village of Torrejon de Ardoz, about 15 miles from Madrid. Its buildings are ultra-modern, and a great effort is now being made to complete its laboratories. Those of the Materials Division, for example, are the best-equipped in the whole of Spain. The Aerodynamics Division has a low-speed wind tunnel for tests on scale models of conventional aircraft ; a propeller test tunnel will be available shortly ; an intermittent variable-pressure supersonic tunnel with a measuring section of 6.6 in. by 6.6 in. and capable of speeds beyond Mach 4 is projected.



The building of the Institute's propulsion Division, with engine test houses.

View of No. 1 wind tunnel. Undergoing tests is a model of a Spanish-designed twin-engined transport (probably the ASA 207 *Azor*).



One of the Institute's constant preoccupations has been to keep in close touch with corresponding establishments in other countries. In order to stimulate interest in the study of modern aeronautical problems, it is organizing engineering courses and lecture cycles by prominent scientists. At the same time, it is sending its own research workers abroad to familiarize themselves with aeronautical progress in other countries.

An important part of the Institute's activities is the training of future aeronautical engineers. These attend the Aeronautical Engineering College *(Escuel Especial de Ingenieros Aeronáuticos)*, for which the Ministry of Education is responsible. To qualify for the College, students must pass an entrance test which is designed mainly to determine their standard and abilities in the field of mathematics. Students stay at the college for five years and one four-month term. They spend the last two years as internes at I.N.T.A. to familiarize themselves with modern aeronautical problems and enable them to engage in practical research work. Particularly proficient students may qualify for a scholarship at the Institute from the fourth year of their studies and thus take part in specialized research work earlier than provided for under the regular curriculum.

GREGORIO MILLAN BARBANY,
TORREJON DE ARDOZ

Ramjets and the Work of René Leduc

Any means of accelerating the flow of air round an aircraft can, in theory, be used for propulsion. For example, use could be made of the expansion properties of gases heated under constant pressure to obtain the desired acceleration. Such is the general definition of thermo-propulsive ducts, of which gas turbines can be said to be variants, with ramjets representing the "pure form," without moving parts. According to the Carnot principle, a gas can transform part of its internal energy into mechanical energy only by expansion. It is also known that this property can be utilized to transform heat into work, the result improving the higher the rate of expansion between the moment when heat is applied and the moment when expansion ceases. In other words, in any power plant which uses a gas returning (after expansion) to its initial pressure, it is of advantage to heat the gas under the highest possible pressure.

In a thermo-propulsive duct the maximum pressure that can be expected before heating —and during heating—is the so-called stagnation pressure, i.e. the pressure when the air comes to stagnation. Heating should therefore be effected at a point as near as possible to the stagnation pressure (isobaric heating). As the efficiency of thermo-propulsive ducts is connected with the compression ratio, it improves as flying speed increases and is very low at low speeds. Fuel consumption varies accordingly. If, for example, it is 2.2 lbs. per pound thrust per hour at Mach 2, it increases to 3.3 lbs./lb.t/hr. at Mach 0.8.

In essentials, a thermo-propulsive duct will consist of a heating—or combustion—chamber fed with air compressed by simple deceleration, and an expansion chamber where the air expands to the ambiant static pressure in the desired direction of thrust. There is no reason, in principle, why the "admission" air should not be drawn into those parts of the aircraft where flow is naturally slowed down, i.e., on frontal surfaces such as the wing leading edges. In practice, except perhaps in very large aircraft, this arrangement would not be very satisfactory because of the structural complications it would entail. It is therefore preferable to provide a special frontal surface containing the air intake. At subsonic speeds at any rate, the minimum compression losses would be obtained if compression could be carried out entirely outside the power plant. In practice, if only for reasons of external aerodynamics and the desire to keep the fuselage diameter as small as possible (aircraft drag), the air intake will be divergent, and deceleration and hence compression of the air will be completed, if not carried out in full, inside the intake duct.

Because of these same considerations of external aerodynamics, combustion is not made truly isobaric, which means a small sacrifice in efficiency. Isobaric heating would need a sharply divergent combustion chamber, and the necessary increase in the fuselage diameter would entail an increase in drag out of all proportion to the gain in power plant efficiency. Total efficiency, the only kind that counts, would be lower. In general, therefore, the combustion chamber is cylindrical or only slightly conical.

The expansion chamber will naturally consist of a convergent tube, narrowing in the direction in which it is desired to collect the thrust.

The above describes the basic elements of the ramjet, without going into details of any special geometric form.

In theory at least, the designer enjoys great freedom, since all he has to produce is a housing for a column of air subjected to heating, without any of the limitations imposed by moving parts.

René Leduc in conversation with his test pilot Gonord (white overalls). Left, the pilot of the mother aircraft, Commandant Perrin (with pipe).

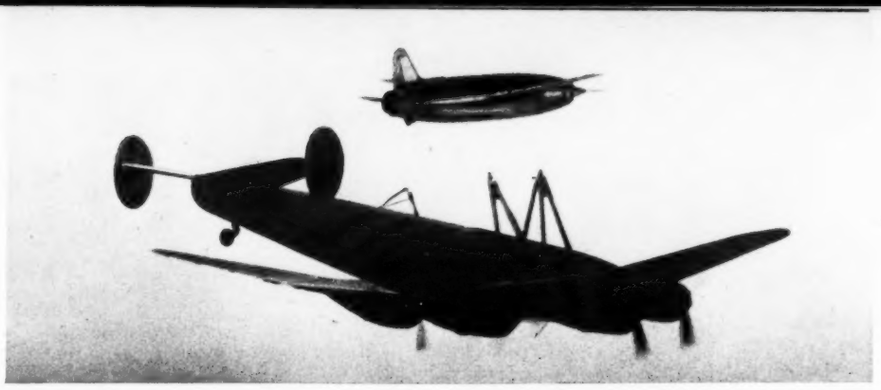
The ramjet's light weight enables considerable thrust to be developed without greatly reducing the fuel load carried.

In the lower supersonic ranges, where the turbojet, even with reheat, is too heavy to give an aircraft the thrust necessary for level flight, it will be replaced by the ramjet.

In spite of its higher consumption, which, however, is very much lower than that of a rocket engine of comparable weight, the ramjet is already of definite interest in the high subsonic range. It will be used in special cases, where it is desired to obtain high thrust for a relatively short time—for example in an interceptor fighter.

A four-engined *Languedoc* taking off into the cloud-filled sky, carrying a Leduc 010 ramjet aircraft.

The ramjet's efficiency rises from a mediocre 10% at the speed of sound to more than 22% at Mach 2, a figure approaching that of piston engines, and then goes even higher.



The test altitude is reached, and the ramjet aircraft separates from the mother aircraft.

History of ramjets

Despite the fact that ramjets are of interest only at relatively high speeds, this type of engine was envisaged as far back as the beginning of the century, at a time when designers dared not think of speeds of even a hundred miles an hour. But World War I brought so many more urgent problems that scientific pastimes with no immediate practical applications completely fell into oblivion.

By whom and when were the first ideas of ramjets conceived ? Nobody quite knows. But this applies to all inventions, and the usual custom is to take into consideration only written information on the subject that has had the fortune to survive.

On the basis of this, it can be said that the first idea of obtaining propulsion by simply heating air in a pipe goes back to 1907, when a patent was taken out by the American *Lake,* who unfortunately had completely erroneous ideas of the principles of thermodynamics.— The first tenable theory of ramjets was described in 1913 by the Frenchman *René Lorin* in the review "Aérophile." These two documents were lost sight of and did not come to light again until recently, after the rediscovery of ramjets in 1930.

Credit for the first practical work on this question must go to *René Leduc* in France, followed by *Paul Schmidt* in Germany. Both at first studied propulsive ducts with intermittent combustion and took out their first patents in 1930, Leduc on February 4th and Schmidt on April 24th. As nobody in France took any interest in this type of power plant, Schmidt was the only one to follow up his original ideas, which culminated in the V1 of World War II.

Meanwhile René Leduc was working on pure ramjets, unaware of the work being done at the same time by the Italian aeronautical engineer, *G. A. Crocco.* In 1933-34, Leduc took out a number of patents on ramjets.

In 1936, after a series of laboratory tests in which he succeeded in stabilizing combustion, he at last obtained thrusts which conformed to his calculations. At the same time, with the cooperation of *Jean Villey,* Professor at the Faculty of Science, Paris, he completed his technical studies. In 1937 he undertook the design and construction, under Government contract, of the first ramjet aircraft, the *Leduc 010.*

Completed in 1940, but too late to fly before the French armistice, it was dismantled and hidden in the South of France, where it was later severely damaged in the Allied bombing. After the war it was rebuilt and flew in 1949, justifying the hopes placed in this new type of power plant.

Today there are a number of designers working on ramjets to power aircraft or guided missiles, at any rate in France and the United States. However, the important work done by Eugen Sänger and others in Germany between 1938 and 1945 deserves special mention. If the fortunes of war had not interrupted work in France for five years and brought German efforts to a standstill just as they were about to bear fruit, France and Germany would have advanced far ahead of the rest of the world in the field of high-speed propulsion.

René Leduc

René Leduc was born in 1898 near Corbeil, in the southern out-skirts of Paris. His family, of modest circumstances, had neither the custom nor the means to give their children an advanced education. However, he early gained a taste for learning and studied intensively during his spare time. In 1916 he enlisted in the Artillery "for the duration"— and went on studying whenever he had a spare moment. He went as a cadet to the School of Artillery, Fontainebleau, where he came out at the head of his class, doubtless owing to his aptitude for study. Demobilized in 1919, he decided to devote his meagre savings to taking a course at one of the big technical colleges. He chose the *Ecole Supérieure d'Electricité,* not because he was interested in electricity—his bent was rather towards mechanics—but because courses there were the shortest and the least costly.

Having gained his diploma but still no more deeply interested in electrical engineering, he went to work as an engineer at a cellulose factory in the Tyrol. He returned to France in 1923 and took a job, more or less by chance, at the Ateliers Louis Bréguet, where he became head of the Bureau de Calculs. He became deeply interested in aircraft, and his brilliant engineering talents were revealed in his designs, the Bréguet 27 and the wing of the Bréguet 730 flying boat. In 1927 he submitted a doctor's thesis to the Academy of Sciences entitled "Contribution to the Study of Prismatic Beams."

He remained with Ateliers Louis Bréguet, where he designed his first ramjet aircraft, until after the war, then left to found a company in his own name. His first workshop was a disused garage at Toulouse, where he repaired his original Leduc 010, damaged during the war. In 1949, at the request of the French Air Ministry, which was financing his work, he installed himself as best he could near Paris, in an abandoned factory. Here he is continuing his new designs, despite the inadequate accommodation.

René Leduc's designs

Even if it is only intended to power a small aircraft of three tons, a ramjet must be so large that it is not possible to design it independently and then fit it to an existing aircraft. The simplest solution is therefore to design a fuselage in the form of a pipe, and this is the basic idea which we find in all the Leduc aircraft that have appeared so far.

Designing the wings presents no major difficulty. Leduc's progress in ramjet aircraft, however, would have been very much more rapid if he had not himself had to solve a mass of secondary problems on which he could not get adequate help from the various specialized industries.

The high fuel flow required, out of all proportion to what was known before the war, necessitated equipment which was not available at that time. Leduc therefore had to design and build special high-power pumps. He then needed a motor to drive the pumps and other accessories, a motor that could be housed comfortably in the pipe. Only a gas turbine could meet these requirements. . . but this type of engine was unknown in aeronautical engineering in 1937. However, Leduc made a gas turbine, one of the first aviation turbines in the world, which was completed in 1940.

Faced with the scepticism of the experts, he made his own first landing gear, and his work in this field led recently to the design of a wheel whose most striking feature is its small bulk.

One of the two Leduc 010 prototypes. The pilot sits in a pressure-tight cabin in the centre of the fuselage and is separated from the outside world by two walls.

Servo controls had to be provided for use at very high speeds. These too he had to make himself. He therefore made a special study of servo controls and is now perfecting them in collaboration with *Société Jacottet*.

The location of the pilot in front of the jet pipe raised a complicated safety problem, as it is practically impossible to get out of the cabin in an emergency. Leduc is therefore evolving a method by which the whole cabin can be parachuted, and the pilot leaves it only after reaching the ground.

For very high altitudes the cabin must be pressure-tight and have air conditioning. These too were such novel features before the war that Leduc again had to work them out himself.—Such are some of the multifarious problems which had to be faced.

*

The programme of experiments envisaged, with the aircraft built or under development, falls into three stages :

1. preliminary investigation of the functioning of ramjets at high subsonic speeds, without special regard for high performance ;

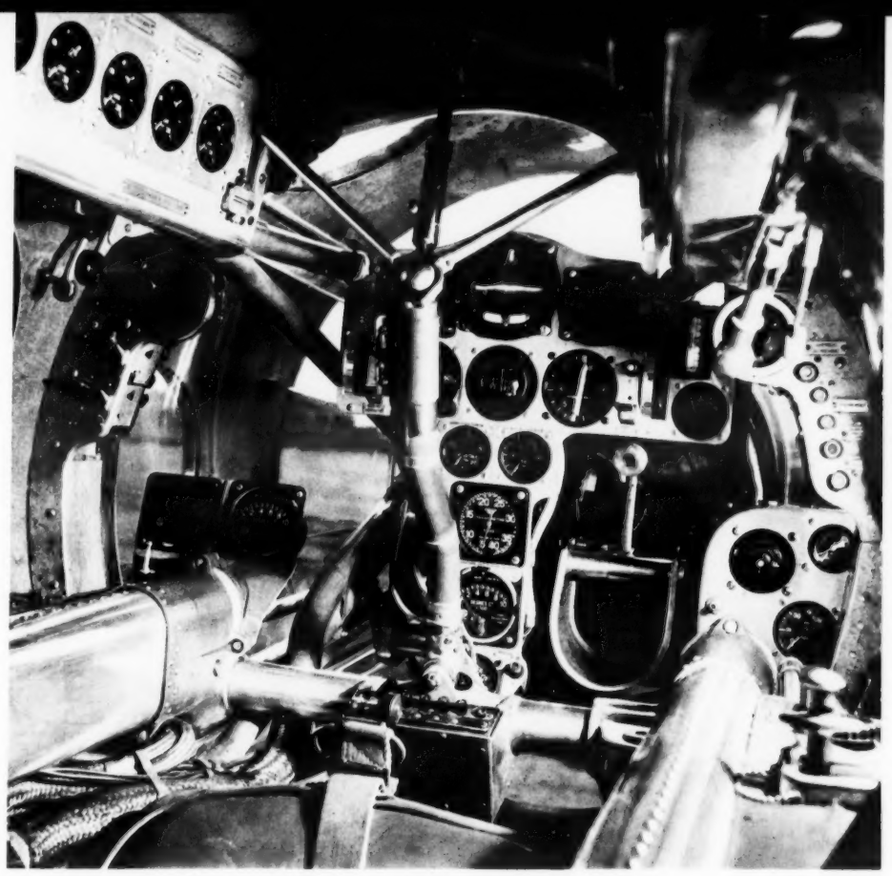
2. experiments with high-power ramjets at high altitudes with special regard to very high rates of climb in the subsonic range ;

3. experiments with supersonic ramjets.

The aircraft corresponding to the first stage are the *Leduc 010* and *016*, which have been flying since 1949 and have already made more than 250 test flights. Those for the second stage, which may be regarded as an intermediate stage between the preliminary investigations and the construction of supersonic ramjets, are the *Leduc 021* models now being completed. A *supersonic ramjet aircraft*, the culmination of all this work, is under development.

Leduc 010 : This aircraft is now well known, as its characteristics have been published in quite a number of journals. It is an all-metal monoplane designed in 1936-37 and differs from the classic aircraft only in its fuselage-

The latest version of the French subsonic ramjet aircraft (Leduc 021) features a pressure cabin (jettisonable?) placed well forward, and a single-track undercarriage.



Inside the pilot's cabin in the Leduc 010... with view into the "outside world."

duct with annular air intake in front, round a central structure containing the pilot's cockpit. Dimensions : length 33 ft. 7 ½ ins.; span 34 ft. 5 ½ ins.; wing area 172 sq.ft.; gross weight 6,600 lbs.

As forecast, a Mach number of 0.84—limited by the airframe and not by the power plant—was obtained, and rate of climb is 1,860 ft./min. at 36,000 ft.—Two aircraft of this type were built.

Leduc 016 : It differs from the 010 only in detail, chief of which is the installation of Turboméca *Marboré* turbojets in the wing tips to provide power at low speeds. Only one built.

Leduc 021 : Aircraft weighing 11,000 lbs. similar to the two above but with a single-track undercarriage and a pilot's cabin far ahead of the air intake. Its ramjet, will have a thrust coefficient nearly three times as great as that of the ramjet in the 010, i.e. roughly 13,200 lbs. thrust (instead of 4,400 lbs.) at 620 m.p.h. Power plant is two Turboméca *Marboré II* turbojets. The Leduc 021 is 41 ft. long and spans 38 ft. 4½ ins. The very high ratio between thrust and gross weight at high speeds promises a rate of climb of roughly 39,400 ft./min.

The Air Hostess Told Us...

The Millenium, says Esmeralda, our Favourite Air Hostess, has arrived. The lion lies down with the lamb, peace is universal, and the airlines have stopped cutting each other's throats. No more competition—but cooperation down to the last detail. Take Pan American World Airways and Trans World Airlines, for example, the two big American international operators who a few years ago fought a terrific slanging match before the C.A.B. in Washington about the various Atlantic routes each one tried to keep the other away from. Nowadays they do everything in perfect unison, it seems, even the preparation of those beautiful calendars they distribute to their friends at the end of each year. Proof ? Reproduced here are the PAA and TWA calendars for June 1953. Subject of the illustrations ? Neuschwanstein Castle in Bavaria in both cases, the white marble abode built by Mad King Ludwig II from 1869 to 1886.

Too good to be true, says Esmeralda. Coincidence can play funny tricks. Perhaps it was the same photographer who sold the colour shots to the two airlines.

Accent on Defence or Sound Economy?

On June 3rd, 1953, President Eisenhower appeared before the television cameras with a laundry basket of personal mail to give his fellow citizens a glimpse of his daily duties. He fished out a letter from a housewife in Rhode Island, who complained she could no longer make head or tail of the complicated budget figures published every day. Eisenhower assured her that he found himself in the same position at times . . .

Do other people manage any better?

The whole question of the American budget could be ignored as a matter of purely American domestic interest, were it not for the facts that Wendell Wilkie, the late Republican candidate for the Presidency, had raised the banner of "One World" years ago, that thousands of Europeans buy American cars and nylons, refrigerators and washing machines, and millions of Americans buy French cosmetics, Paris fashions, British textiles, Swiss watches, German beer—and the other good things the Old World produces. Above all, the Truman Administration created the Marshall Plan, American aid to Europe, NATO, the European Defence Community—and before taking office the present President was not only the liberator of Europe but also, in his capacity as Commander-in-Chief of the NATO forces, for a time almost a citizen of Europe.

When, therefore, the new President's Administration announced early in May that it intended to reduce its defence budget, and in particular its Air Force appropriations, Europe was directly affected. For years past it has been hammered into Europeans that the United States Air Force, especially its long-range bomber fleet and atom bombs, was Europe's shield and protector. Is this shield suddenly showing cracks? Anyone reading American newspapers and periodicals must be tempted to reach this conclusion.

With a disarming smile, President Eisenhower admits to the journalists that the American budget figures give him a headache . . . Incidentally the journalists don't fare much better.

"Engine Charlie's" Air Force budget

Chris Roberts, our Washington correspondent, is a reliable man. In March 1953 he sent us a report entitled "Eisenhower Cabinet Promises Strong Air Power."[1] The new President, he said, had formed his Cabinet from the heads of industry. The appointment of Charles E. Wilson—for many years President of the mighty General Motors Corporation and nicknamed "Engine Charlie"—as Secretary for Defence was a happy augury for the aircraft industry and for the expansion of the Air Force. The article, however, ended on a warning note: the new Administration's promises to reduce the budget threw a slight shadow over the picture.

Today, three months later, the shadow has become a heavy cloud in the eyes of many. A "one-shot, second-best air force" is the verdict of General Hoyt S. Vandenberg, who retired from the post of Chief of Staff of the United States Air Force on July 1st.

What had happened?

[1] *Interavia, Review of World Aviation*, No. 4/1953.

The Republican Administration had included two planks in its election platform: to increase the country's defensive strength so as to ensure the nation's protection against all comers, and at the same time to raise the nation's standard of living and reduce taxation. The two promises may seem to many to be an attempt to square the circle. How Defence Secretary Wilson proposes to solve the problem was communicated to the American public in the first half of May:

Fiscal 1954 Defence Budget for the year beginning on July 1st 1953; (introduced by Truman Administration) $41,286,448,000.
Fiscal 1954 Defence Budget (modified by Eisenhower Administration) $36,039,320,000.
Air Force appropriations (introduced by Truman Administration) $16,778,000,000.
Air Force appropriations (as cut by Eisenhower Administration) $11,688,000,000.
Cut in Air Force appropriations $5,090,000,000.

To judge by the first press reactions, the world was falling apart—the Air Force was on the edge of an abyss. The layman, reading that the Air Force budget had been cut by nearly a third, must have been a little taken aback. But at the same time Wilson promised that America would in no way slacken her defence efforts, and the Air Force would be stronger than ever, despite the cuts. He explained this as follows:

1. There were still several thousand million unspent dollars for aircraft procurement from earlier budgets, simply because production capacity had not been able to keep pace with appropriations.

2. Despite the cut of roughly $5,000,000,000 for the 1954 fiscal year beginning on July 1st, the Air Force will get about 15,000 combat aircraft in the coming budget, compared with only about 12,000 in the past budget year; or

Charles Erwin Wilson—nicknamed "Engine Charlie"—exchanged the job of President of General Motors Corp. for that of *Defence Secretary under the Eisenhower Administration*. Saying that 120 properly equipped Air Force wings were better than 143 badly equipped, he cut the 1953/54 Air Force appropriations by $5,090,000,000.

General Hoyt S. Vandenberg, retiring Chief of Staff of the U.S. Air Force, described the Air Force planned by Wilson as a "one-shot, second-best air force."

Roger M. Kyes, formerly Wilson's right-hand man at General Motors, now *Deputy Defence Secretary of the United States.*

The Secretaries of the three armed services—all leading businessmen picked by Defence Secretary Wilson: *Robert T. Stevens*, Secretary of the Army; *Robert B. Anderson*, Secretary of the Navy; *Harold E. Talbott*, Secretary of the Air Force.

to be exact, annual production will be increased by 3,150 aircraft.

3. Despite the cut, the U.S. Air Force will still be the most powerful air force in the world and have more long-range bombers than the Red Air Force.

4. No reduction will be made in research and development, except for the atom-powered prototype, which must be regarded as somewhat fantastic at the present time.

5. The economies made would be "only" about 1,150 supporting aircraft, i.e., transports, helicopters, reconnaissance aircraft etc., and the Air Force's first-line strength would remain unchanged.

6. Fantastic production figures must be reduced to sensible proportions, as firms cannot hope to reach exaggerated targets. But even if the highest production goals were reached, little would be gained, because of the ensuing shortage of flying personnel, ground crews, installations, equipment and armament.

What do Wilson's Air Force budget changes really amount to?

Robert A. Lovett, his predecessor—in co-operation with Thomas K. Finletter, the Democratic Air Force Secretary—had set himself two goals, the *143-wing programme* and the target date of July 1st, 1955, based on an estimate of Russia's will and ability to attack, by which this programme was to be completed. Charles E. Wilson—in cooperation with the Republican Air Force Secretary, Harold E. Talbott—is now contenting himself with a *120-wing programme* and refuses to set any target date. He will be satisfied if he gets a first-line strength of 116 wings by July 1st, 1954 . . . and of 120 wings by July 1st, 1955, all equipped with modern jet aircraft. These aircraft must be fully armed—armament has hitherto been a weak point. In March 1953 the Air Force officially counted 103 wings, but at least ten of them had obsolescent equipment.

A revolt of the Generals?

Let us quote once more our Washington correspondent, who was full of optimism in March this year, but two months later reported certain dramatic turns of events.

Admiral Arthur W. Radford, the new Chairman of the Joint Chiefs of Staff, opposed the billion-dollar programme for the B-36 in 1949, but has now pledged himself before the Congress to safeguard the interests of all armed forces, including the Air Force.

". . . Muffled rumblings over the apparent philosophies of the new Eisenhower Administration began two months ago and have steadily mounted in intensity . . . The first open blast was issued by Representative Yorty (California) when he declared: 'We cannot afford to have the Defence Department headed by a defeatist Secretary, whose vision is so circumscribed by dollars, profits and grossly exaggerated economic strain that he is willing to concede the Soviet's dominance of the air indefinitely . . .'."

And indeed a kind of storm did break out in Washington and elsewhere in the American press about the middle of May, and it is not yet possible to say whether it was a storm in a teacup or not. It rose to further heights with the appointment of new officers to the top command posts in the United States armed forces and above all by the *appointment of Admiral Arthur W. Radford as Chairman of the Joint Chiefs of Staff*. Admiral Radford, aged 57, had taken a leading part in the 1949 dispute between the Air Force and the Navy. He was regarded as the leader of the "Revolt of the Admirals," who had opposed the Air Force, its strategic bombing programme and the giant B-36 bomber and demanded a stronger Navy with a number of super aircraft carriers and a powerful air arm. This is the man to whom the welfare of all three armed forces has been entrusted.

The opposition is mobilizing itself.

Former Democratic Air Force Secretary Thomas K. Finletter accuses Wilson of endangering the Strategic Air Command—and hence the basic principle of Western security—with his 120-wing programme; of showing the mentality of an infantryman and blindness to a potential Russian threat. As a compromise Finletter proposes that the Navy and the Air Force be combined.

General Vandenberg, retiring Chief of Staff of the Air Force, testifying in a three-day hearing before Congressional committees, recalled the reasons for the 143-wing programme, namely American obligations overseas, the existence of the Russian atom bomb, and the war in Korea, and maintained that all these reasons still hold good today.

Press comments, too, were typical:

Hanson E. Baldwin, writing in the *New York Times* on June 2nd, considers as ridicu-

General Nathan F. Twining, the new Chief of Staff, U.S. Air Force—at 55 nearing retiring age—has been appointed for two years only. It has been suggested that this is so as to leave a chance open for General Lauris Norstad, "the Air Force's youngest general."

Eisenhower's Joint Chiefs of Staff: left to right: *General Matthew B. Ridgway*, Chief of Staff, U.S. Army (formerly Supreme Commander, Allied Forces in Europe); *Admiral Robert Carney*, Chief of Naval Operations (formerly Commander-in-Chief, Allied Naval Forces, Mediterranean); *Admiral Arthur Radford*, Chairman of the Joint Chiefs of Staff (formerly Commander-in-Chief, U.S. Naval Forces, Pacific); *General Nathan F. Twining*, Chief of Staff, U.S. Air Force (formerly Vice-Chief of Staff).

lous the statement that United States air power could be strengthened by budget cuts. Playing with figures was misleading, and the results of the economies would not be seen in full until 1955, when present contracts run out. By seeking to cut out the supporting planes (transports, reconnaissance aircraft, helicopters etc.) Wilson was weakening the whole defence programme. The 143-wing air force was to have included 17 transport wings, without which there could be no military airlift or airborne landings. By cutting the reconnaissance aircraft, the long-range bombers would be robbed of their "eyes." The Air Force would be tied down to obsolescent machines . . .

In the *New York Herald Tribune* the Alsop Brothers commented that the Russians would have a fleet of all-weather jet fighters at the latest by 1955 and would then become increasingly invulnerable. The 143-wing programme provided for 57 strategic bomber wings, but today there are only 40 in existence, most of them with obsolescent equipment (B-29s, B-50s and B-36s), and the prospects of getting the $10,000,000,000 required to re-equip them with Boeing B-52 eight-jet bombers are dim. How was General Curtis E. LeMay, one of the most brilliant of America's Air Force officers, to carry out his duties as Commanding General of Strategic Air Command?

So far General LeMay has not played a very noticeable part in the discussion, but it begins to look as if he might turn out to be the strongest opponent of Wilson and his budget cuts. At any rate Wilson aimed pretty plainly at him when he said he would "have to whistle for the new administration building he wants out in Omaha . . ."

The crux of the matter

On January 1st, 1948, a memorandum was submitted to President Truman—and a little later to the general public—that has since made history and on which the whole rearmament programme for the U.S. Air Force has been based. This memorandum bore the ominous title "*Survival in the Air Age.*" It was the final report of the Air Policy Commission appointed by President Truman to consider the future of American aviation in all its branches. The Commission was headed by the New York attorney Thomas K. Finletter, whom we find a short time later as Secretary of the Air Force and responsible for planning its organization and the much-disputed 143-wing programme.[2]

In 1948 the United States had an aircraft industry that had been reduced to poverty by disarmament, an ailing air transport system and an out-of-date Air Force of 55 wings, with 580 medium bombers and roughly 2,300 fighters, almost all piston-engine types.

The 1947/48 Finletter report came to the following conclusions: no foreign air force

Thomas K. Finletter, Democratic Air Force Secretary under the Truman Administration, accuses Wilson of endangering the strategic air force—and hence the basic principle of Western security.

was likely to have, before 1952, supersonic aircraft or guided missiles capable of threatening the American continent. However, atomic weapons could not long remain a monopoly of the United States, but could be expected to become available in other countries between 1951 and 1957. Hence a radical change in the United States' "traditional peacetime strategy" was imperative. The result was the formation of the Strategic Air Command designed to carry atomic bombs, and General Curtis E. LeMay was recalled from Wiesbaden to head it.

The Finletter report called for a strength of 50 first-line wings by 1952, adequate reserves, and 700 modern super-heavy jet bombers. It also recommended the rapid implementation of the U.S. foreign air bases policy, the development of guided missiles and an expansion of the aircraft carrier fleet.

Soon afterwards American planners met with a number of unpleasant surprises. The activities of Klaus Fuchs, Pontecorvo and the rest of the atom spies allegedly speeded up Russian atomic research. Then came the stiffening in relations between America and Russia, the first atomic-bomb explosion in Russia, the Berlin airlift, the fighting in Korea and in Indochina. The result was inevitable: the 70-wing programme of 1948 became the 143-wing programme of 1953. But President, Air Force Secretary, Chiefs of Staff have since changed, *and now there is another new plan, the 120-wing programme.*

It would be stupid to imagine that a man who has been as successful in private business as Charles E. Wilson could be a fool or a defeatist. His Air Force Secretary Harold E. Talbott comes from a family that has been very closely connected with aviation for two generations. The new Chairman of the Joint Chiefs of Staff, Admiral Radford, was opposed not to the Air Force as such, but to what he termed the "billion-dollar blunder," i.e., the expenditure of vast sums of money on the Convair B-36 long-range bomber—perhaps he was not so far wrong at that—and demanded the continuation of the carrier programme which had been cut at that time. He has just sworn before Congress to be a true guardian of all the armed forces, including the Air Force.

On the industrial side, the presidents of the major manufacturing concerns, such as North American Aviation, Douglas, Boeing, Lockheed, Convair or Northrop, announced, after discussions in Washington, that production would not be cut, at any rate for the time being, and that they would not have to lay off a single worker. On the other hand it seems to be beyond doubt that Wilson will do away with "dual source procurement," the system of relying heavily on auxiliary or shadow concerns to support production.

If we are to accept the views of some of the generals, such as General Vandenberg or General LeMay, there is danger for the United States Air Force in delay. Judging from comments in the *New York Times*, the Republican *New York Herald Tribune* or, at first, in *Time* and *Newsweek*, their fears would appear to be justified. On the other hand it cannot be denied that General Lauris Norstad, Commander-in-Chief of the NATO air forces in Central Europe, who is tipped as tomorrow's Air Force Chief of Staff, as well as Vandenberg's successor, General Twining, have accepted the budget cuts without visible signs of anxiety. The *U.S. News and World Report*, which has close relations with Washington officials and is extremely well informed, approves and defends Wilson's measures.

An unbiassed reader of the American press would probably decide that the arguments marshalled by the Air Force generals on the opposition side appear to be more firmly based than those of the clever civilian Charles E. Wilson. The reverse would be more logical. However, it would seem even more illogical that these American generals should suddenly start talking about threats and dangers, while the civilians are evidently more reserved. "Security" has changed over to the civilian side...

Is the Eisenhower Administration afraid that America might "overarm," as the Russians hoped a few years ago?

Do the Americans think that Europe has been sufficiently strengthened for them to return to a modified form of isolationism and hence to an easy withdrawal from Europe?

These are questions to which the civilians, in their hearings before the Congressional committees, give no answers. They have taken their decisions and seem to be determined to carry them through.

In a speech on June 10th President Eisenhower said that the conflict between the free world and Communism is not a purely military struggle, but also a scientific, intellectual and above all an economic one . . .

At the moment the American Air Force faces a cut in its appropriations. For the United States as a whole the question seems to be *whether armament or economy shall come first.* Without an orderly economy there can be no security, even with a powerful air force. If we are not mistaken, this has already been proved before. *EEH*

[2] Cf. *Interavia, Review of World Aviation*, No. 2/1948, p. 104.

What's in the Air ? *

AIR POLITICS

● Seventh Session of ICAO Assembly

The *Seventh Session of the International Civil Aviation Organization Assembly* opened at Brighton, England, on June 16th, 1953. Its work is expected to take it three to four weeks. Chairman of the meeting, which is being attended by representatives of 51 ICAO member States, three non-member States and five international organizations, is *Sir Frederick Tymms*, who has represented Britain on the ICAO Council since 1947. The three working committees are headed as follows : *Technical Commission : Lt. Col. Luis Azcárraga* (Spain) ; *Economic Commission : René Lemaire* (France) ; *Administrative Commission : Brig.-General C. S. Booth* (Canada). — Shortly before the opening of the Session the Republic of Honduras was admitted as 60th member of the International Civil Aviation Organization.

Sir Frederick Tymms has been elected Chairman of the Seventh Session of the International Civil Aviation Assembly, which opened at Brighton, England, on June 16th, 1953. Sir Frederick, who has represented Britain on the I.C.A.O. Council since 1947, was Director General of Civil Aviation in India from 1945 until India's independance in 1947.

● Turkey plans Directorate of Civil Aviation

The Director of the International Civil Aviation Organization's European and African Bureau recently visited Ankara and Istanbul to advise the Turkish authorities on the creation of a *Directorate of Civil Aviation*. ICAO is to send three experts to Turkey for a year to train the necessary personnel.

SERVICE AVIATION

● New N.A.T.O. College Commandant

Air Vice Marshal L. Darvall, of the Royal Canadian Air Force, is to take over command of the *North Atlantic Treaty Organization College* in Paris in December 1953. The present Commandant of the College, which was founded in 1951, is the French Admiral André G. Lemonnier.

● U.S.-Canadian air exercise

" Exercise Tailwind " is the name of the joint *United States-Canadian air exercise* to be held in July. Aircraft of the U.S. Strategic Air Command will simulate an attack on Canada, and R.C.A.F. bombers will " raid " industrial centres in the United States.

● Airfield demolition preparations in Germany

Preparations by the American forces for the demolition of West German airfields in the event of war are reported from Nuremberg. Plans for boring demolition holes in the runways at Nuremberg Airport, however, have been postponed, upon representations by the airport management (Nordbayerische Flughafengesellschaft m.b.H.) and the airlines using the field, as it would have meant closing the airport for several weeks.

● Japanese exercise at American training ground

Japan's National Security Corps (forerunner of a new Japanese defence force) held its first major exercise since the war, at the U.S. Garrison Force's training ground near Fujiyama, from June 16th to 21st. *Aircraft* from the *Hamamatsu Aviation School* took part.

AIR TRANSPORTATION

● P.A.L. Pacific service

Philippine Air Lines is shortly to open its new direct service from *Manila to San Francisco and Mexico City*, to be operated by DC-6s and DC-6Bs. It is the first company to offer luxury services between San Francisco and Mexico City.

● Drive-in ticket office

United Air Lines has opened a drive-in ticket agency in Redwood City, California, to serve passengers living in the " Peninsula " area south of San Francisco. Sales agents at two windows enable motorists to buy tickets without leaving their cars. More extensive information is given under a covered parking area.

● All's well that ends well

Trans World Airlines has completed payment of a $17,921,170 aircraft mortgage, covering twenty *Constellation* airliners. The mortgage was arranged with a group of fourteen banks in March 1948.—At the time the sum was regarded as a high one and TWA as showing considerable optimism in engaging itself to such an extent when air transportation prospects did not seem good.

● Preliminary report on Calcutta Comet accident

" Structural failure of the airframe during flight through an unusually severe thundersquall ", resulting in fire breaking out on board the aircraft, probably caused the accident to B.O.A.C.'s *Comet* near Calcutta on May 2nd, according to the report prepared by the Indian Court of Enquiry. " A study of the different components and the nature of their failure strongly suggests primary failure of the elevator spar in bending, due to a heavy down-load imposed in a pull-up by the pilot when the aircraft encountered a sudden down-gust . . . with the resulting wing failure at about rib No. 7." The structural failures caused fire to break out (fuel over hot engine parts ? — Editor).

The fact that the aircraft caught fire in flight appears to contradict—at any rate in certain cases—the earlier assumption that the use of kerosene would greatly reduce fire risk. Fuel experts state that kerosene, heated on the ground to certain critical temperatures and rapidly carried to altitude, becomes very volatile, creating highly inflammable fumes.

* Extracts from INTERAVIA AIR LETTER, daily international news digest, in English, French and German. All rights reserved.

The Italian Air Force has received forty Fairchild C-119 *Flying Boxcar* transports from the United States under the arms aid agreement. The first two have already been ferried from the Fairchild Works at Hagerstown, Maryland, to Pisa, where they were handed over by *Major General James G. Christiansen* (left), Chief of the U.S. Military Assistance Group in Italy, to *General Aldo Urbani* (right), Chief of Staff, Italian Air Force.

The first *Douglas DC-7* four-engined airliner took off on its first flight from Santa Monica, California, on May 18th, 1953.

Potez 75 light anti-tank aircraft, built by Société des Avions et Moteurs Henry Potez.

● Atlantic competition from Iceland

Loftleidir H/F, the Icelandic air transport company (a close collaborator with Braathens S.A.F.E.), which does not belong to the International Air Transport Association, has announced reduced fares on its Copenhagen-New York services. The new fares are 270 Danish crowns lower than the *tourist rates of other Atlantic airlines* for a single trip, and no less than 500 crowns less for a return ticket . . . It remains to be seen what the U.S. Civil Aeronautics Board will say.

INDUSTRIAL

● Backlog of aircraft orders

The total value of orders on the books of *aircraft, engine and propeller* manufacturers at the end of March was $18,502,000,000 compared with $17,653,000,000 at December 31st, 1952, the U.S. Department of Commerce reports. Increase over the first quarter of 1952 : 35 %. Orders received during the first quarter of 1953 amounted to $2,873,000,000 and formed roughly 16 % of the total backlog on March 31st, 1953.

● Rolls-Royce and Westinghouse collaborate

Rolls-Royce Ltd. and *Westinghouse Electric Corp.*, Philadelphia, have signed an agreement for *technical cooperation* for a period of ten years (exchange of information in design and production of gas turbine engines, exchange of personnel and possible future licence arrangements). Westinghouse has already made Rolls-Royce an initial payment.—In view of Westinghouse's recent production difficulties with the J-40 and J-46, the agreement comes as no surprise.

● Arms aid for Fiat

Fiat S. A., Turin, has been granted a loan of $3,700,000 out of Mutual Security Agency funds, to finance tooling for Allison J-35 engine parts production. The company's Lingotto works has received a N.A.T.O. order for $9,000,000 worth of these parts.

AIRCRAFT

● Reference has already been made on several occasions to a civil version of the Avro *Vulcan* four-jet bomber. This airliner, known under the designation Avro *Atlantic*, is still in the development stage, but could be ready for delivery by 1958 if orders are received early enough. However, work will only be continued if the Ministry of Supply orders at least two prototypes, and a production order for at least 20 aircraft is then guaranteed.—Provisional data for the *Atlantic* show that it will be larger than the *Vulcan* : span 121 ft ; length 145 ft. ; gross weight roughly 200,000 lbs., with a max. payload of over 45,000 lbs. Power plant, as in the Vulcan, will probably consist of four Bristol *Olympus* engines.—Mean cruising speed would be 600 m.p.h. at 40,000 ft., and there would be accommodation for 76 to 131 passengers.

● According to unconfirmed reports, *Northrop, Lockheed and Douglas* are all working on new "*light-weight fighters.*" The Douglas design is said to be a development of the F4D *Skyray* (XF5D ?), and the Lockheed is probably the F-104. All the major aircraft manufacturers can be assumed to be working on designs of this kind.

● The new *North American F-100* supersonic fighter is reported to have begun fight testing at Edwards Air Force Base. The F-100 has a 45° swept wing.

● A new *Douglas A4D* Naval low-level attack aircraft is under development.

● Two models have been selected for prototype construction in the French *design contest for a two-seater trainer* organized by the Sports and Light Flying Service : the *Nord 3200* (low wing monoplane with fixed tail-wheel undercarriage ; engine in the 170 to 260 h.p. class ; e.g. the 230 h.p. Potez 6 D 00, 260 h.p. Salmson 8 AS 04 or 170 h.p. SNECMA 4 L 02) and the *Farman Monitor II* (240 h.p. Salmson-Argus ; second prototype planned with SNECMA 4 L 02).

● The *Potez 75* light all-metal two-seater with fixed nose-wheel undercarriage designed especially for *anti-tank* and ground support operations, is armed with an undisclosed number of guided missiles. It is powered by a 450 h.p. Potez 8 D 32 engine driving a pusher propeller and weighs 5,290 lbs. ; cruising speed 152 m.p.h.; range 465 miles.—Special features : armoured underside of fuselage (for low-level flight) ; simple, cheap mass production ; easy maintenance in the field.

● The Spanish firm of *Aeronautica Industrial S. A.* reports that a new all-metal communications aircraft, the *AISA I-18*, is ready for flight testing. The same firm is also working on two helicopter projects : the *AISA IH-51*, a two-seater with jet-powered two-bladed rotor ; and the *AISA IH-52*, a two-seater with piston engine, main rotor and anti-torque tail rotor.

POWER PLANT

● Besides constant efforts to improve the *ATAR* turbojet, *SNECMA* is also working on an *afterburner for later ATAR versions*. Plans are to try out the afterburner in the 101 D version of the ATAR and use the experience gained here in the development of the 101 F (8,800 lbs. static thrust with reheat).—A first ATAR engine with reheat was subjected to a test run on March 31st, 1953, when a thrust of 8,380 lbs. (with reheat) was measured.—Work on the *Vulcain* turbojet is also continuing. The static thrust of this engine at sea level is 9,920 lbs., a value reached during test runs in November 1952.

● The *jet deviation system developed by SNECMA* has the following features : immediate transition from positive to negative thrust ; control of negative thrust ; use in turbojets with reheat.—SNECMA's first test bed runs with jet deviation were made in a BMW 003 engine, and in July 1952 flight tests were made in a D.H. *Vampire* fitted with the device. The following results have been announced for first practical tests in a D.H. *Goblin* (normally fitted in the French Air Force's *Vampires*) : runway required by *Vampire* without jet deviation 850 to 1,100 yards ; with jet deviation 425 yards (with wheel brakes in both cases).—Other work in this field concerns the adaptation of the jet deviation system to engines of the most varied power classes, e.g. the Turboméca *Piméné* of 220 lbs. thrust or the SNECMA ATAR 101 C of 6,200 lbs. thrust. Finally intensive research into the use of jet deviation with afterburners is also under way.

Payload of the Bréguet 763 Deux Ponts — Correction

The article entitled " The Impact of Cargo on Air Transport Planning " in No. 5/1953 of *Interavia, Review of World Aviation* included a table (p. 254) showing very rough figures for the percentage of gross weight represented by payload in a number of commercial transports. Payload of the Bréguet 763 was here given as 22 % of gross weight.

The manufacturers now tell us that weight distribution for the Bréguet 763 is as follows :

Operating weight empty (airframe, power plant, equipment, crew)	61,100 lbs.
Payload of pure cargo version	35,200 lbs.
Fuel	13,700 lbs.
	110,000 lbs.

The percentage of payload (variable according to movable equipment) is therefore 32 %.

STANDARDIZATION OF LANDING PROCEDURES FOR MODERN RADIO AIDS

by P. CAROUR, Ingénieur de la Navigation Aérienne

(Conclusion) [1]

PROCEDURE A

As fig. 3 shows, the direction of the QDR vector for a given QFU remains unchanged. On the other hand the radius of the orbiting arc depends on the speed of approach, the wind, the advance or delay with which the aircraft crosses the vertical through 0 in relation to the time of arrival as calculated by control.

The controller decides the moment at which the aircraft shall leave the QDR vector. A very simple computer solves the problem.

- The aircraft equipped with VOR/DME can follow the whole procedure without the aid of radar.
- The aircraft equipped with VOR only easily follows the QDR vector ; control gives it the moment at which it should begin the standard turn for alignment on the orbiting arc, then, putting itself on a course prescribed by control or by observing the steady variation in the VOR readings, it orbits, makes a standard turn and lines itself up on QFU.
- The aircraft equipped with a radio compass only flies on the prescribed track, following the compass readings and later instructions from control.

All aircraft, regardless of their radio equipment, can thus land at a constant rate.

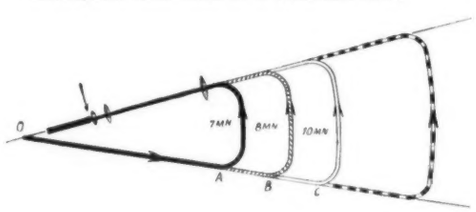


Fig. 3 : Diagram of procedure A. Point 0 is marked by VOR, DME and MF transmitters.

Safety :

Assuming three aircraft arriving at point 0 at three different altitudes and flying on the same QDR vector away from the beacon, the one flying at the highest altitude will immediately begin to descend. It may then collide with the aircraft at the lower altitudes.

So that there should be no risk of collision, it would be necessary to have a time interval, based on the speeds of approach and the wind, between the aircraft as they pass over point 0. For example, with no wind, the aircraft flying at 120 knots should pass over 0 at least 40 seconds before the aircraft at 150 knots and 1 minute 10 seconds before the aircraft at 180 knots, if the two latter are at lower altitudes. These limitations caused procedure A to be abandoned.

PROCEDURE B

In fig. 4 the radius of the orbiting arc remains invariable regardless of the QFU in use. On the other hand the direction of the QDR vector depends on the speed of approach, the wind and the advance or delay with which the aircraft crosses the vertical through 0 in relation to the calculated time of arrival. Before the aircraft arrives at 0, the controller tells the pilot which QDR vector to follow (similar computer to that described for procedure C). Tracks are followed in the same way as for procedure A.

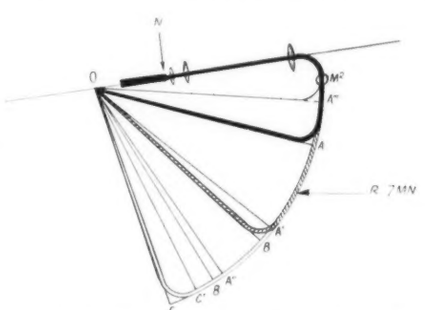


Fig. 4 : Diagram of procedure B. Point 0 is marked by VOR, DME and MF transmitters.

Safety : The aircraft's entire progress is followed by the surveillance radar, which is particularly efficient, as no separation in altitude is necessary. The risks of collision have been examined ; the most critical case has been found to be the following :

Two aircraft flying at 120 and 180 knots respectively arrive simultaneously over 0. The 180-knot aircraft is assigned to the QDR vector marked in double lines, the 120-knot aircraft to a vector 48° to the left of the former, marked by a thick line. The 120-knot aircraft will then reach the critical point of the common arc only fifty seconds before the 180-knot aircraft. A strong wind might still further reduce this margin. Procedure B is therefore also abandoned.

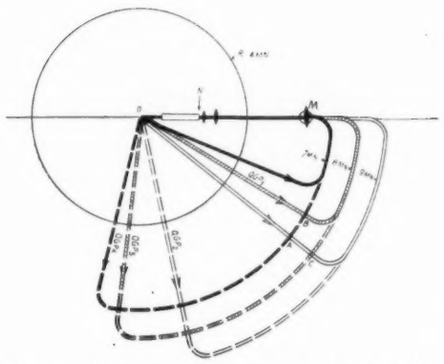


Fig. 5 : Diagram of procedure C. Point 0 is marked by a VOR/DME/MF group.

PROCEDURE C

In this procedure (fig. 5) the length of the QDR vector depends on the approach speed of the aircraft : its direction depends on the wind, and the advance or delay with which aircraft fly over 0 compared with the time estimated by control. A circle about 0 as centre, with a radius of 4 nautical miles is used for calculating the QDR vectors to which aircraft are allocated (cf. figs. 2 and 5).

When an aircraft arrives over point 0 *ahead* of the estimated time, it uses up this extra time by flying on a radius which forms a larger angle with QFU than the vector which would normally be allocated. When an aircraft arrives over point 0 *behind* the estimated time it can, within certain limits, make good the delay by flying on a radius which forms a smaller angle with QFU (up to about 15°, i.e., the angle required for turning on to QFU, provided the aircraft can then present itself at the required altitude). Fig. 6 shows the solution to the first problem (aircraft ahead of time).

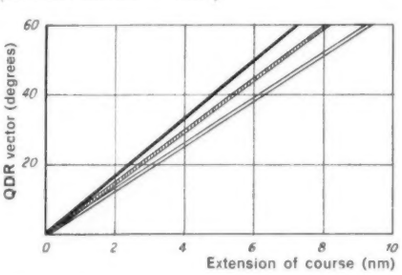


Fig. 6 : Absorption of advances in procedure C. An increase of 4 nm in course, for example, absorbs 120 secs. for a 120-knot aircraft, 100 secs. for a 150-knot aircraft and 80 secs. for a 180-knot aircraft.

[1] Cf. Interavia, Review of World Aviation, No. 6/1953, pp. 348-349.

An important point is that the length for lining up on QFU is directly proportional to the speed of approach, which facilitates the presentation and landing of high-speed aircraft.

Influence of wind on total time of process : Wind force and direction affect the total time taken for the approach process, which must be taken into account in calculating QDR vectors. For example, for a 30-knot S.E. wind at 45° to the runway, corrections for the QDR vector of a *120-knot aircraft* are as follows (cf. fig. 5) :

QGP2 circuit : 2 degrees (7 seconds difference from no-wind circuit),

QGP4 circuit : 7 degrees (20 seconds difference from no-wind circuit).

For the *normal circuit* the difference from the no-wind circuit would be only two seconds, and no correction would be required.

These times are longer for aircraft with speeds of less than 120 knots, but are reduced by 20 % for an aircraft flying at 150 knots, and 35 % for an aircraft flying at 180 knots.

Safety : The aircraft's progress is followed throughout by surveillance radar which, as in procedure B, is particularly efficient here, as aircraft are not required to fly at separate altitudes. In addition the trajectories prescribed by control are marked on the scope, which permits of very great precision. Risks of collision have to be examined at points A, B and C :

At A, the 120-knot aircraft would have to be ahead of its timetable, and its complementary trajectory would have to be to the right of that of the 180-knot aircraft, but as the latter always flies faster than the 120-knot aircraft, it would have passed point A before it ; in the least favourable case, that of no wind and the two aircraft passing over point 0 simultaneously the 120-knot aircraft will arrive at A a full *3 minutes 10 seconds* after the 180-knot machine.

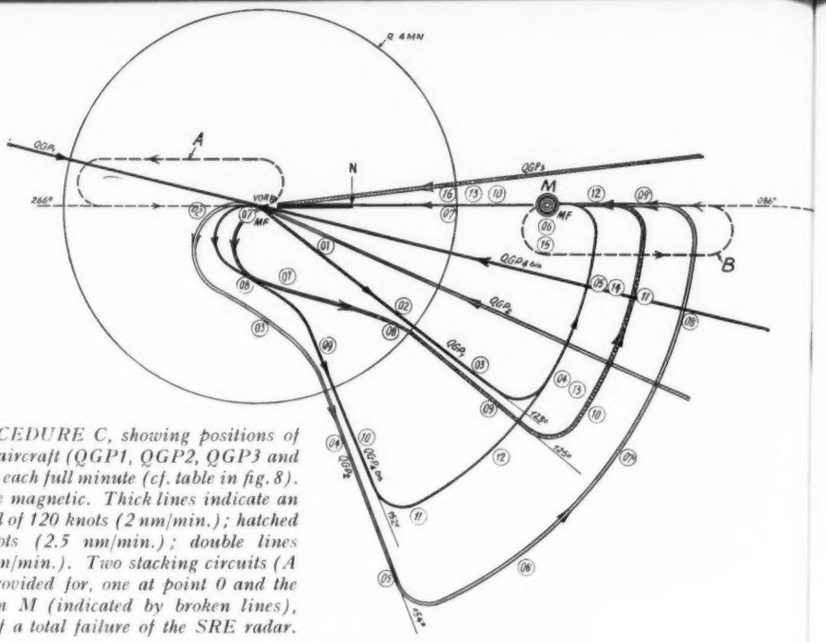


Fig. 7 : PROCEDURE C, showing positions of four different aircraft (QGP1, QGP2, QGP3 and QGP4 bis) for each full minute (cf. table in fig. 8). All courses are magnetic. Thick lines indicate an approach speed of 120 knots (2 nm/min.); hatched lines 150 knots (2.5 nm/min.); double lines 180 knots (3 nm/min.). Two stacking circuits (A and B) are provided for, one at point 0 and the other at beacon M (indicated by broken lines), for the event of a total failure of the SRE radar.

At B, in the least favourable case, of no wind and the two aircraft (120 and 150-knot) passing over point 0 simultaneously, the 120-knot aircraft will pass over point B *3 minutes 10 seconds* after the 150-knot aircraft.

At C, in the least favourable case, of no wind and the two aircraft (180 and 150 knots) passing over point 0 simultaneously, the 150-knot will pass *3 minutes 10 seconds* after the 180-knot aircraft. Allowing for a S.E. wind of 30 knots at an angle of 45° to the runway, the 150-knot aircraft, 3 minutes in advance of its timetable, will pass over point B 3 minutes 10 seconds after the 180-knot aircraft.

Fig. 7 shows the position, at the end of every minute, of four different aircraft (QGP1, P2, P3, P4 bis) marked in the table. The spacing between the aircraft following these trajectories is clearly seen. At point 0 the aircraft are separated by 1,000 ft. in altitude. *The degree of safety offered by this procedure is therefore adequate.*

EQUIPMENT REQUIRED FOR PROCEDURE C

The following equipment is required :
surveillance radar in duplicate,
scopes with accessories,
two types of computer,
tables showing progress of aircraft.

The SRE radar should give sufficient cover to enable the operator to follow arrivals at the VOR/DME/MF group, turns on to QDR and trajectories. The zone not covered, vertically above the radar, must be as small as possible. There must also be elimination of permanent echos.

As indicated earlier, it is desirable that these procedures be followed not only under I.F.R. but also under V.F.R. conditions. As point 0 in this procedure is on the airport, the advantages of a direct approach in certain cases are much smaller. The result will be a tendency for Visual Flight Rules to disappear from use at class A and B airports. Hence, as all approaches are identical, they

Fig. 8.

Regional Control Centre (C.C.R.)						Approach Control (APP)											
1 Call-sign	2 Approach speed (kn)	3 QAH over 0 (m)	4 ETA over 0 (hr.min)	5 QDM (degrees)	6 Aircraft's equipment	7 QGP	8 Calculated time over 0 (min. sec)	9 Calculated time over Cf (min. sec)	10 Actual time over Cf (min. sec)	11 Advance (min. sec)	12 Delay (min. sec)	13 Unabsorbed delay (min. sec)	14 QDR vector (degrees)	15 Actual time over 0 (min. sec)	16 Calculated landing time (min. sec)	17 Actual landing time (min. sec)	18 Landing delay (sec)
F-CD	120	500	10 : 00	100	MF	1	01 : 00	59 : 00	58 : 10	00 : 50	—	—	123	01 : 10	08 : 00	07 : 50	—
G-AB	180	1100	10 : 01	290	VOR/DME	2	04 : 00	02 : 40	00 : 40	02 : 00	—	—	154	04 : 20	11 : 00	11 : 10	10
F-BC	150	800	10 : 04	260	VOR	3	07 : 00	05 : 40	04 : 50	00 : 50	—	—	125	06 : 50	14 : 00	14 : 30	30
C-ND	180	500	10 : 12	250	VOR/DME	4	10 : 00	08 : 40	10 : 50	—	02 : 10	01 : 00	100	10 : 10	17 : 00	17 : 00	—
F-DZ	150	1100	10 : 13	300	MF	5	14 : 00	12 : 20	12 : 00	00 : 20	—	—	125	13 : 40	21 : 00	20 : 40	—
E-EF	120	800	10 : 13	10	VOR	6	17 : 00	15 : 00	12 : 00	03 : 00	—	—	160	17 : 10	24 : 00	23 : 50	—
F-GH (Alternative)	120	1100	10 : 04	280	VOR	4 bis	10 : 00	08 : 00	05 : 00	03 : 00	—	—	152	07 : 00	17 : 00	17 : 20	20

will always be followed by radar, and visibility becomes an entirely secondary matter for the controller.

The arrangement of the control room is shown in fig. 9. Desks, numbered from left to right, are :

Desk 1 : Regional Control Centre (*Centre de Contrôle Régional* = C.C.R.) controller and assistant. The scope shows the ground installations within a radius of 30 to 40 nautical miles.

Desk 2 : Approach controller No. 1 and assistant (APP). Scope shows the airport and surrounding air space against a reference circle with a radius of 4 nautical miles. The operator follows the aircraft's movements from its first crossing of the reference circle to the second. His assistant does the calculations.

Desk 3 : Approach controller No. 2. Scope shows complete procedures. The controller here checks the aircraft's movements in particular from its second crossing of the reference circle to its lining up on QFU.

Desk 4 : GCA controller. Two precision scopes for landing.

Desk 5 : Watch leader *(Chef de Quart)*. Scope similar to that at desk 3.

Each controller (except the GCA controller) has a cathode ray D/F equipment. There are three aircraft progress tables between desks 1, 2, 3 and 4 ; as soon as a controller marks up an item of information, it appears on the three tables. The altitudes not in use are marked up by the controller at desk 2 and noted underneath each table. The aircraft passes through the hands of all four desks from 1 to 4, and then to the airport control.

Marking the trajectory on the SRE scopes : If the radar controllers are to follow the aircraft's movements on the prescribed trajectories, the latter must be able to appear on the scopes as required. In view of the large number of possible trajectories, the problem is very difficult to solve electronically.

The following solution (fig. 10), however, is simple. Runways, beacons and markers are shown permanently on the radar scope. A transparent protractor centred at point 0 (VOR/DME/MF group) has small holes along its diameter corresponding to the various approach speeds. In addition, lines parallel to the diameter enable courses to be given to aircraft without VOR/DME. A compass rose is marked on the periphery of the radar scope.

The controller marks (with the aid of a coloured pencil) on the scope the aircraft's magnetic course of arrival at point 0, the QDR vector, and the circular path (by inserting the pencil in the hole corresponding to the approach speed).

Now that the trajectory has been drawn, the controllers can follow the progress of the aircraft and give it all the necessary instructions at the proper time. The surveillance scope thus becomes similar to the GCA controller's precision scopes.

Computer I : To determine the time required by the aircraft to fly from the reference circle to point 0, making allowance for the wind. The periphery of the computer is marked from 0° to 360°, and the disc has a number of concentric circles graduated in time. There are also two alidades, one for the wind, the other for the aircraft's magnetic course to point 0. Air speed added to the wind cuts the magnetic course and gives ground speed and time required.

Computer II : To determine the QDR vector. The periphery of the computer is calibrated from 0° to 360°, and time curves representing delays or advances in relation to the ETA are marked on the disc. One alidade, attached to a central disc, is used to mark the aircraft's magnetic course before arrival at point 0. A second alidade, on which approach speeds (in kilometres, knots or statute miles) are indicated, enables a first QDR vector to be fixed according to the advance or delay. The central rose attached to the first alidade then gives the corrections in degrees, corresponding to the time required for turning from QDM on to QDR. Finally, allowance is made for wind.

Progress tables

These tables, an example of which is shown in fig. 8, are needed to ensure a regular flow of traffic. Entries are made by the *Regional Control Centre* (C.C.R.) and the *Approach Control* (APP).

Fig. 9 : Diagram of Approach Control room for procedure C.
CCR/APP = Progress table of Regional Control Centre and Approach Control

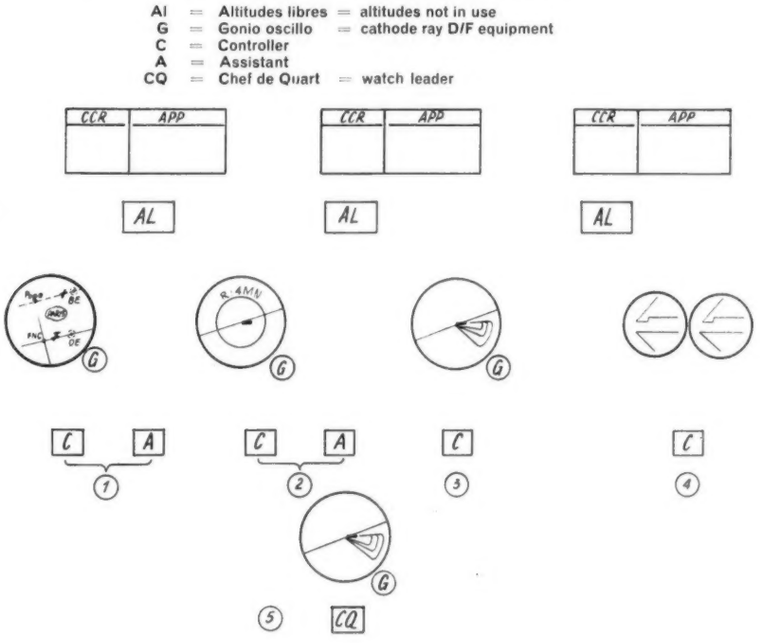
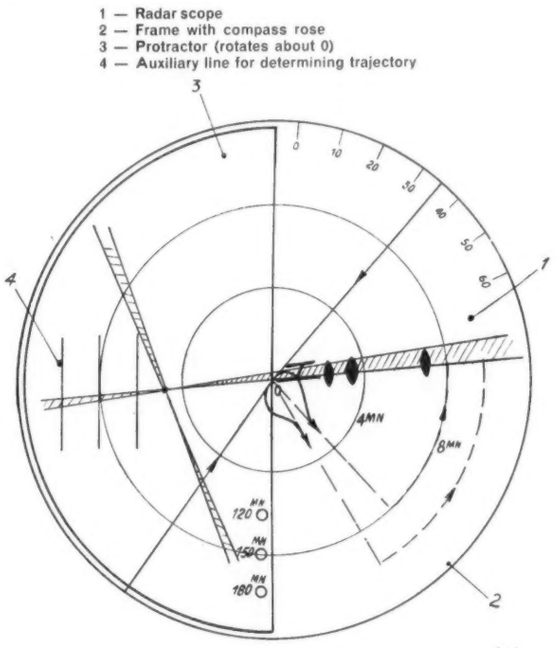


Fig. 10 : Diagram of an accessory for marking aircraft trajectories on the radar scope. Runways, beacons and markers are drawn permanently on the scope, whereas approach trajectories are entered as required.



Five minutes before the aircraft's ETA over point 0 the *C.C.R. controller* enters : (1) the aircraft's registration letters or call sign, (2) approach speed (indicated air speed) at first crossing of the reference circle, (3) altitude on arrival over point 0 (QAH), (4) estimated time of arrival at 0, (5) magnetic course followed by aircraft from the reference circle to 0 (QDM), (6) the aircraft's equipment (VOR/DME-VOR-MF). Then *Approach control* enters : (7) aircraft landing order (QGP), (8) estimated time of arrival over point 0 (determined by adding *3 minutes* to the previous QGP time). This time may be modified by a non-absorbed delay by the previous aircraft, (9) estimated time of first crossing of the reference circle, deduced from the above time with the aid of computer I.

All entries by Regional Control Centre or Approach Control can be made four minutes before the aircraft's actual arrival at 0. As soon as the aircraft crosses the reference circle, (10) actual time of crossing is noted, (11) the *advance* or (12) *delay* in relation to the estimated time is calculated, (13) while advances are always absorbed by the procedure, non-absorbable delays have to be noted as they immediately modify the estimated time of arrival over point 0 of the next aircraft. (14) QDR is determined with the aid of computer II.

Approach Control's calculations are now complete and the radar operators follow the aircraft, noting : (15) actual arrival over 0 (so as to modify course from 0 if necessary), (16) estimated landing time, (17) actual landing time, (18) *delays* in relation to estimated landing time. *The practical example* shown in fig. 8 illustrates above all the wide differences in QDR. Wind has been assumed to be zero. It will be seen that all advances have actually been absorbed, but that aircraft QGP4, though assigned to the shortest trajectory (QDR 100°), still had one minute's delay. Time calculated for QGP5 to cross the vertical through 0 " on time " will thus be 14.00 instead of 13.00. As aircraft QGP4 and QGP5 have the same estimated time of arrival, the aircraft with the higher approach speed is given priority and the other is thus automatically regarded as being in advance by 3 minutes ; these are absorbed by assigning the aircraft to QDR 160°.

As landing delays compared with the calculated times do not in this example exceed 30 seconds, there is no need to modify the aircraft's trajectories en route.

Altitudes of arrival at point 0

All aircraft arriving at 0 make their standard turn, *maintaining a constant altitude for one minute*, then descend at 2.5 m/sec., or 1,000 ft. in 2 minutes. The altitude is thus freed in theory 3 minutes after the aircraft passes over point 0. In practice this time can be reduced according to the divergence between the trajectory of arrival over 0 and the QDR vector.

When an aircraft's arrival trajectory overlaps the pattern of its predecessors, it will in general be advisable to instruct it to arrive at the highest scheduled altitude. On the other hand, when the arrival trajectory is outside this pattern, the controller can choose any altitude. As a rule he will make use of the lowest.

TASKS OF CONTROL

The *Regional Control Centre* instructs crews at the appropriate time to put their aircraft into the approach condition before crossing the reference circle and to maintain their speed strictly constant until they have lined up on QFU.

Close cooperation between Regional Control Centre and Approach Control is ensured by installing a scope and two Regional Control operators in the Approach Control room (cf. Fig. 9).

The role of *Approach Control* has been described in its main outlines above. Aircraft trajectories will be calculated on the basis of their crossings of the reference circle and point 0. Landing rate can be reduced to three minutes.

To attain this goal Approach Control's calculations must be strictly accurate, aircraft must follow instructions exactly, and approach speed must be constant.

Unfortunately, errors of all kinds will cause variations in the landing rate. Corrections will sometimes have to be made by Approach Control while aircraft are flying on their prescribed trajectories (after the second crossing of the reference circle). In practice, such corrections will only be made when the time interval between two aircraft risks being less than 2 minutes.

The landing rate can be restored by varying the aircraft's speed, the direction of the QDR vector or the length of the QDR vector.

Aircraft's approach speed : It would be tempting to vary approach speed, as in this way trajectories, once fixed, could remain unchanged. In practice, to change speed on the trajectory at the request of control handicaps the crew, and pilots' opinions are very divided on the advisability of this measure. Other methods should therefore be sought, even if this one is not discarded altogether.

Direction of QDR vector : This can always be changed if instructions are given in good time. In this way the trajectory can be lengthened or shortened.

Length of QDR vector : It is also possible to change the length of the QDR vector in order to modify the aircraft's trajectory.

Only experience can show whether corrections need be made en route and, if so, what will be the best method of making them.

BREAKDOWN PROCEDURE

Surveillance radar failure

Even though surveillance radar equipment is provided in duplicate, the possibility of a complete failure must be allowed for. Let us examine once more fig. 7 in which the positions of aircraft QGP1, P2, P3, P4 bis (cf. " aircraft progress table " in fig. 8) are indicated at times t, t+1 (01), t+2 (02), etc.

The first APP controller marks the trajectory of the aircraft approaching point 0 according to the C.C.R.'s indications, and fixes QDR as a function of the speed of approach.

Let us imagine that a complete radar failure takes place at time 08 : the Regional Control Centre representative in the control room is immediately aware of the failure and diverts traffic en route to other airports, if necessary. On the other hand, aircraft near point 0 are instructed to stack over point 0. Finally, aircraft in the pattern beyond point 0 receive new instructions from Approach Control.

As the trajectories of the aircraft have been traced, the controllers can mark their positions at the time of the SRE failure. Aircraft continue their route, following the pilot's judgment, but receive the following instructions : *QGP1*, which is already on QFU, is immediately taken over by the precision approach radar.

QGP2 also continues its circular path, and the controller gives it an altitude for arrival at M, where it stacks.

QGP3 receives instructions, at the proper time, to home on M at an altitude 1,000 ft. above QGP2. The same applies to QGP4.

During the radar breakdown, subsequent aircraft stack at 0 and will be instructed to home on to MF beacon M one after the other. Newcomers to point 0 will be instructed to arrive at one altitude (e.g. 5,000 ft.). As soon as the breakdown is repaired, procedure C is applied progressively as before.

Breakdown of aircraft transmitter

If the failure occurs before instructions are received from Approach Control (instructions giving the QDR), the aircraft flies to a reporting point provided for the purpose.

If the breakdown occurs after instructions have been received from Approach Control, the aircraft follows the prescribed trajectory by pilot's judgment ; other aircraft are diverted by APP if necessary.

Breakdown of ground transmitter

As Approach Control is in communication with several aircraft on the same frequency and at the same time, pilots soon become aware of the breakdown and contact the *tower* on its own frequency.

CONCLUSIONS

Procedure C fully meets requirements laid down. Its chief advantages are :

The location of point 0 on the airport enables standard trajectories, applicable to all runways (and QFUs) to be determined ;

the marking of point 0 by a VOR/DME/MF group and the constant check on movements kept by the surveillance radar enable all types of aircraft to use the procedure ;

the elimination of stacking and the provision for aircraft to present themselves at point 0 at two or three different altitudes facilitate the flow of traffic ;

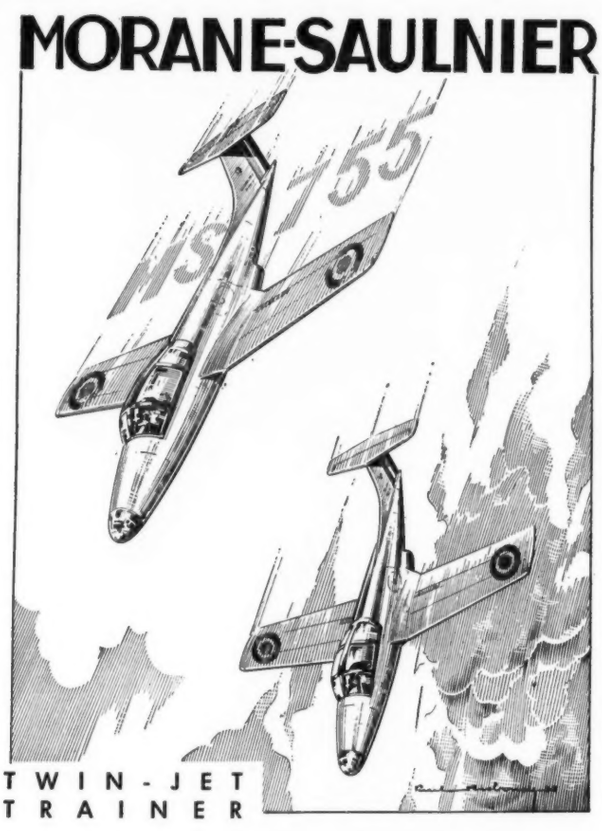
the calculation of trajectories and their rapid entering on the radar scopes ensure a constant landing rate ;

as no separation in altitude is necessary during the procedure, the surveillance radar is particularly efficient in keeping track of aircraft's respective positions ;

the degree of safety provided by procedure C can be deduced from the above ; pilots' and controllers' tasks are simplified.

*

Procedure C is shortly to be tried out in France at Orly and Le Bourget airports, and it would be helpful if other airports too could adapt it for their own use. When perfected in detail, it should enable approach procedures to be standardized and simplified.



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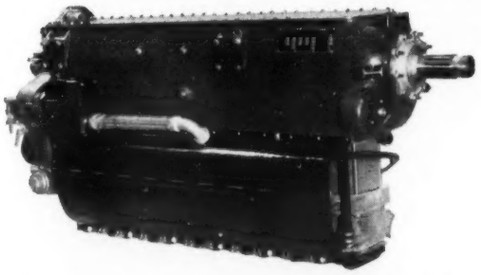

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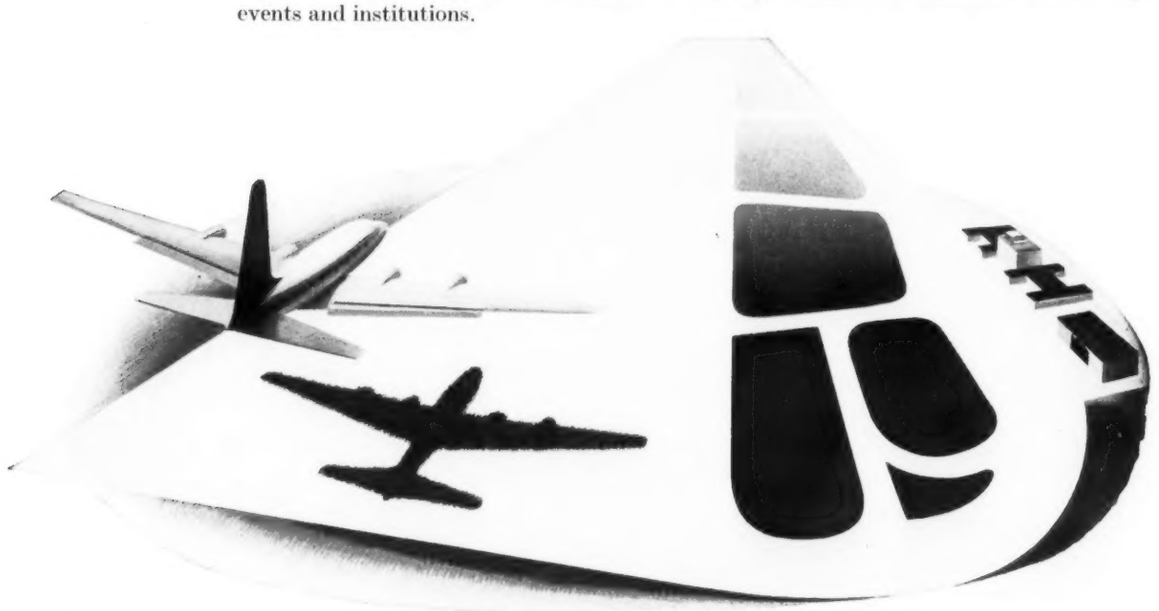

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